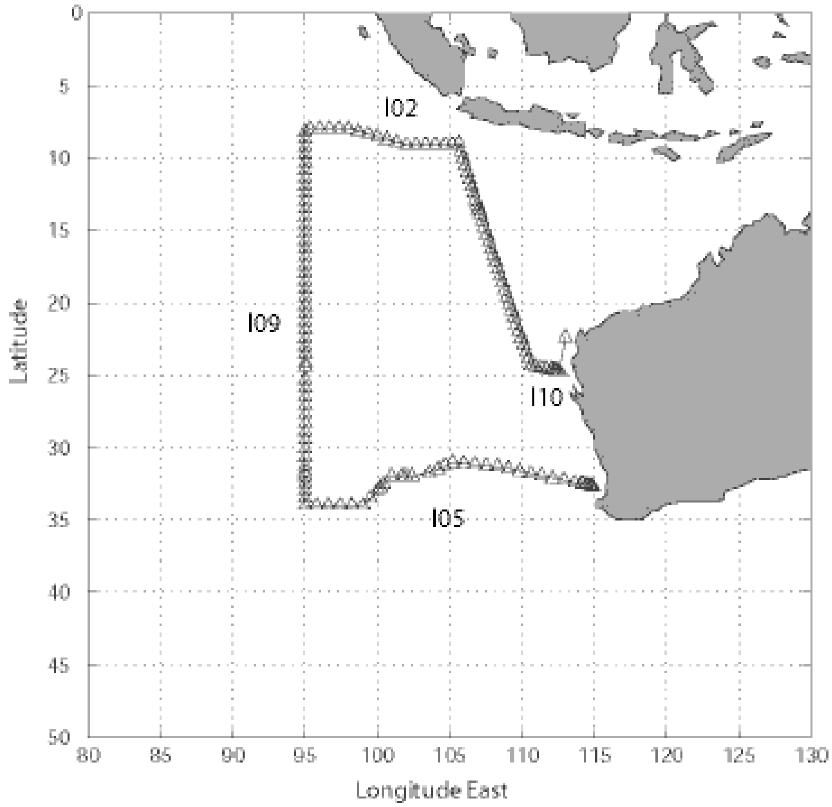
CRUISE REPORT: I02

(Updated JUL 2009)



Highlights

Cruise Summary Information

Section designation	**I02**
Expedition designation (ExpoCodes)	**09FR20000926**
Chief Scientists	**Susan E. Wijffels / CSIRO**
Dates	14 OCT 2000 - 12 NOV 2000
Ship	***R/V FRANKLIN***
Ports of call	Cocos Islands, AUS - Fremantle, AUS
Geographic boundaries	8.0 S 94.99 E 114.87 E 34.01 S
Stations	142 CTD Stations
Floats and drifters deployed	0
Moorings deployed or recovered	0
Chief Scientist Contact Info.	Susan E. Wijffels CSIRO Marine Research GPO 1538 Hobart, Tasmania 7000 Australia Phone: 03 6232 5450 Fax: 03 6232 5123 e-mail: Susan.Wijffels@marine.csiro.au

Links to text locations

Shaded sections are not relevant to this cruise or were not available when this report was compiled

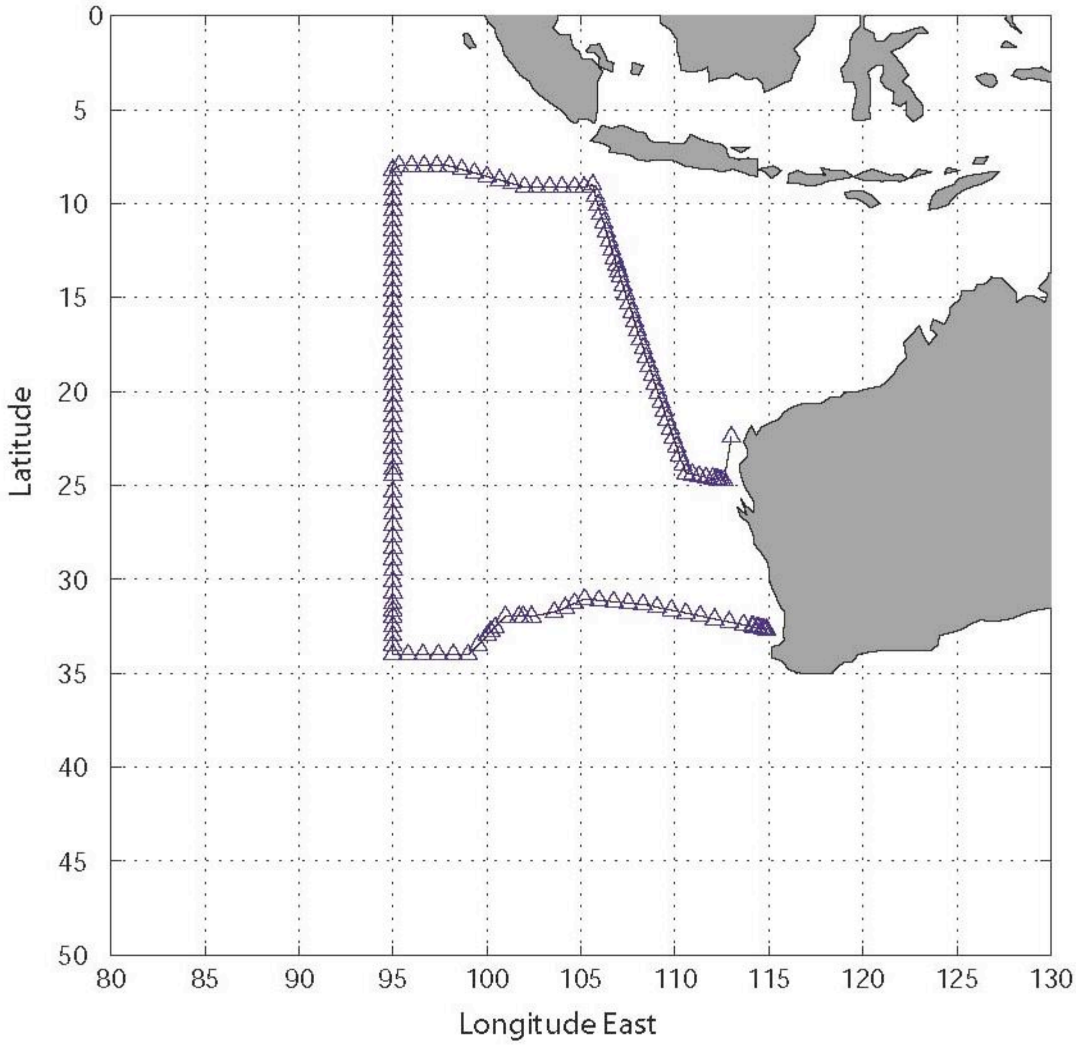


Figure 1: Hydrographic stations occupied during the cruise are indicated by triangles.

CRUISE SUMMARY

RV FRANKLIN
FR09/2000

Title

Monitoring Ocean Climate Change around Australia: the Deep Ocean Time-series Sections.

Itinerary

Leg 1

Departed Dampier, 1000 hrs Tuesday 26 September, 2000.
Arrived Cocos Islands 0900 Saturday, 14 October 2000.

Leg 2

Departed Cocos Islands, 1600 hrs Saturday, 14 October 2000.
Arrived Fremantle, 0030 Tuesday, 31 October 2000.
Departed Fremantle, 1300 Tuesday, 31 October 2000.
Arrived Fremantle, 1330 Sunday, 12 November 2000.

Principal Investigators

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Email: Susan.Wijffels@marine.csiro.au

John A. Church, Steve R. Rintoul, Bronte Tilbrook
CSIRO Marine Research

Nathan Bindoff
Antarctic Co-operative Research Center
University of Tasmania

Scientific Objectives

- to establish a time series of full-depth repeat ocean measurements capable of resolving decadal and longer time-scale changes in the structure of the oceans around Australia, and their storage of important climate quantities such as heat, freshwater, oxygen and carbon. The proposed surveys will build upon the high-quality sections made in the mid-1990's as part of the World Ocean Circulation Experiment (WOCE).
- to use these data through comparisons with climate model runs to test climate model predictions, and to determine whether and how fast climate is changing due to the Greenhouse Effect and/or natural decadal variability.
- to improve our understanding of basic ocean processes and fluxes through collection of full depth direct velocity measurements while conducting the repeat surveys.

Cruise Objectives

To reoccupy portions of several WOCE hydrographic lines between Australia and 90°E in the southeast Indian Ocean as part of establishing a deep-ocean time-series section grid around Australia. Full-depth 24 bottle 5L Niskin/CTD casts will be taken at WOCE spatial resolution. Sampling and chemical analyses will be completed for salinity, oxygen, nutrients, dissolved carbon and alkalinity. At-sea quality control will occur with all CTD and sample data collected and scrutinised as soon as it is available and compared with the WOCE data.

Cruise Track

Two legs were undertaken (as indicated on Figure 1) – Dampier to Cocos Island and Cocos Island to Fremantle. One test and 62 CTD stations to the bottom were undertaken during leg one, and 80 CTD stations on leg two.

Results

The voyage achieved the cruise objectives. (Scientific Objective 3 was not addressed as no lowered Acoustic Doppler Profiler for attaching to the CTD/Rosette package was available). Of the 143 stations in the original station plan, only one station was missed due to poor weather. Overall, the quality of the data is very high, with some exceptions as described in the Cruise Narrative below.

Exceptions to the otherwise high quality observations included some poor salinity data due to problems with the salinometers early in the cruise and trouble with the nitrate channel of the autoanalyser throughout the cruise. The first problem we believe can be overcome given the stability of the Seabird CTD conductivity sensor; the nitrate data can be recovered by running the second (frozen) nutrient sample taken from each bottle. The new oxygen system gave excellent results.

Preliminary comparison of the WOCE and DOTSS sections shows some significant changes. Most dramatic is a shift of an upper ocean front along the 95°E section. The front was located several degrees of latitude further south during DOTSS than in the WOCE section taken five years before. The frontal shift resulted in temperature anomalies below the depth of the winter mixed layer of more than 3°C and salinity anomalies greater than 0.4 psu. The front (hence the anomalies) extends throughout the upper 500 m of the water column. More subtle but still significant changes occurred at the depth of the Antarctic Intermediate Water.

Cruise Narrative

Leg 1

We departed Dampier on time in good weather, proceeding to the start of the CTD section commencing at about 24°S off the west Australian coast. En-route we completed a trial CTD station to test for leaking bottles. We then commenced the CTD section late on Wednesday 27 September. Winds were light but there was a swell coming from the south.

The new load sensor to measure the tension on the CTD end of the cable worked well but the altimeter on the rosette package was not working for the first few stations. With the swell and the roll of the ship, the tension was momentarily going to zero on the more severe rolls. On station 11 (the first deep station - to 4400 m) there was a kink in the *new* CTD wire on recovery. On station 12 (to 5000 m), the descent speed was reduced to 50 m/minute as the wire tension was going to zero on severe rolls. At about 500 m on the upcast, all contact with the CTD was lost. On recovery the lower 20 m of the wire was severely kinked. After consultation with Ian Helmond (in Hobart), 6500 m of CTD wire was streamed with a weight attached in an attempt to remove any residual twist in the wire. No further problems were encountered with CTD operations; a total of 63 CTD stations were completed on leg one. After the completion of CTD

63 at 1600 on October 13, we steamed to Cocos Island. In total, about 40 m was cut off the end of the CTD cable.

During most of leg 1 we experienced steady south east trade winds at between 15 and 25 knots. This made for easy working conditions except for the steaming between the last few CTD stations and the steam to Cocos Island.

All Niskin bottles were sampled for salinity, oxygen and nutrients. Every second station, samples were also taken for alkalinity. Throughout the cruise, under-way meteorological, surface temperature, salinity fluorescence and upper layer currents were measured.

During the first leg of cruise FR09/00, we intended to test 2 XBT systems - the new Bureau of meteorology (BOM) hardware and the Sippican WindowsNT Software. The BOM system consists of a slower computer with a new IEEE interface. The Sippican software has been designed to work under WindowsNT and has never been tested against a CTD before. The BOM system worked well but the Sippican system could not be made to work on the first leg. A detailed report is attached as Appendix A.

Cetacean and marine wildlife sighting summary (Debbie Thiele)

Cetacean sighting survey effort was conducted during daylight hours on transit legs between CTD stations. A total of eight cetacean sightings (82 animals) were made on the survey. Cetaceans recorded were humpback whales, sperm whales, beaked whales and a range of tropical dolphin species. The frequency of cetaceans observed was low, however sea state conditions for surveying were generally poor to moderate, and rarely good due to the effect of SE winds. When sighting conditions were good, sightings were still rare. There are many factors that determine the distribution and movements of cetaceans. One reason which may explain the low number of sightings is that odontocete (toothed cetacean) prey may be more abundant in surface waters with a lower average temperature than is prevalent in this area at this time of year. Turtles were observed only in near shore waters during the first day of the cruise. Seabirds were present during most days, but not in large numbers. Surface feeding flocks were only occasionally observed after the first day in nearshore waters. Flying fish (very small to large) were also observed each day, but again in low numbers. Marine debris became more common as the ship neared the high seas fishing areas off the Indonesian EEZ.

Leg 2

Weather conditions on Leg 2 were often uncomfortable, with winds rarely below 20 knots and often higher.

As a result of the hard work during Leg 1, the gear on Leg 2 generally worked well. Exceptions included the salinometers and the ADCP. The range of the ADCP steadily decreased through the first part of Leg 2, and eventually no good data was received at all. The problem was eventually traced to a broken bulkhead connector which could not be fixed at sea (a new connector was installed prior to the following voyage). We encountered very few problems with the CTD and rosette system. Near the end of the cruise we encountered some difficulties with firing bottles on several casts. The problem was eventually traced to a combination of a small leak in the termination, a leak in the connector between the load cell and the CTD cable and a poor connection at the junction box on the winch drum.

Deep bottle salinities on the first part of Leg 2 were generally higher than those found on the previous WOCE occupations of these lines. When a new salinometer was used during the latter half of Leg 2, the agreement between the deep WOCE and DOTSS data was very good.

We found the load cell on the CTD end of the wire to be useful when operating in rough conditions. The fact that different load cells and their displays appear to be in different units is confusing and they should be made consistent in future. In rough seas (i.e. when the ship is either pitching or rolling) it is not possible to eliminate occasional transient loads close to zero throughout the cast, at any practical lowering speed. However, we encountered no problems with kinking of the wire associated with low loads on the end of the wire.

We completed several casts to depths greater than 6000 m. The tension at the block was near the limiting value of 1.1 tonnes, but casts to this depth could be done without exceeding this limit by decreasing the winch speed below 4000 m depth (at least in the relatively good weather we experienced at that time of the cruise).

The major event of Leg 2 was the emergency medical evacuation of the Chief Steward, Ron Culliney. On Friday October 27 Ron suffered a suspected stroke. After consulting doctors on shore, we immediately headed for Fremantle as fast as possible. On Sunday evening October 29 we rendezvoused with the Australian Navy vessel HMAS Anzac and Ron was transferred by IRB in very heavy seas and strong winds (8-10 m seas, 40+ knot winds). The operation was completed in the dark. Ron was flown by helicopter from the Anzac to a Perth hospital early Monday morning.

The cruise was extended by 7 days to allow the work to be completed as in the original station plan. Following Ron's transfer to the Anzac, Franklin continued to Fremantle to load the fuel, food, and replacement crew required to complete the work. We tied up at the wharf at midnight Monday October 30, and sailed again as soon as bunkering was complete, at 1300 the following day.

We steamed west to resume the CTD stations where we left off. In total, the diversion to Fremantle and return added more than 2000 nm of extra steaming to the cruise. Steaming west into the strong and persistent westerly winds for four days tried the patience of all on board. The weather continued to be marginal for much of the remainder of the cruise. One station had to be skipped because there was no time to wait on station until the weather improved.

Summary

The most significant difficulty experienced during Leg 1 was kinking of the CTD wire on the first deep stations. However, after this problem was overcome no further difficulties were experienced. Whenever a new CTD cable is fitted there is a need to stream it to remove residual torque and to tension the cable on the drum before it is used for CTD casts. Careful attention was paid to ensure high quality hydrology and CTD data was collected; overall, the data quality is good and should be a valuable contribution to the establishment of long-term time-series sections in the eastern Indian Ocean to measure both natural variability and anthropogenic climate change.

Personnel

Scientific participants on Leg 1

John Church	CMR	Cruise Leader/Manager
Ming Feng	CMR	Watchleader
Linsay Pender	ORV	
Gary Carroll	CMR	
Ann Gronell	CMR	
Erik Madsen	ORV	
Bronte Tilbrook	CMR	
Alain Poisson	LPCM, Paris	
Gary Critchley	ORV	
Rebecca Cowley	ORV	
Neale Johnston	ORV	
Debbie Thiele	Deakin University	

Scientific participants on Leg 2

Steve Rintoul	CMR	Cruise Leader/Manager
Neil White	CMR	
Serguei Sokolov	CMR	
Dan Conwell	ORV	
Pamela Brodie	ORV	
Mark Rosenberg	Antarctic Cooperative Research Centre	
Neale Johnston	ORV	
Val Latham	ORV	
Dave Terhell	ORV	
Mark Pretty	CMR	
Andrew Lenton	CMR	
Juliette Dubois	LPCM, Paris	

Franklin officers and crew members

Ian Taylor	Master
Arthur Staron	First Mate
John Boyes	Second Mate
Ian Murray	Chief Engineer
Robert Cave	First Engineer
Hugh McCormick	Electrical Engineer
Phil French	Greaser
Bill Hughes	Bosun
Terry Ganim	A/B
Tony Hearne	A/B
Norm Irvine	A/B
Gary Hall	Chief Cook
Wayne Hatton	Second Cook
Ron Culliney	Chief Steward

Underway Processing Notes

Data processing completed by Bernadette Heaney, 18 October 2001

1. Voyage details

“Monitoring Ocean Climate Change around Australia: the Deep Ocean Timeseries Sections”

1.1 Principal Investigators

Dr S Wijffels, Dr J Church, Dr S Rintoul, Dr B Tilbrook, CSIRO Marine Research
Dr N Bindoff, Antarctic CRC

2. Underway data

A set of standard “underway” instruments are logged onboard the research vessel “Franklin”; this data is displayed in real time onboard to assist with voyage planning and watch keeping; some of the data is subsequently processed onshore to produce a set of standard underway data.

The data is logged to hourly files; the naming convention is explained in section 4.1 on page 5; (these are referred to as “raw” data files.

The standard underway data set is 5 minute values of ship position (latitude and longitude), water depth, sea surface temperature and sea surface salinity; air temperature, wind speed and direction, humidity, barometric pressure, solar radiation; corrected wind speed and wind direction, ship direction and speed and gust.

A data format guide can be found at

http://www.marine.csiro.au/datacentre/process/formats/uwy.htm

3. Sea surface temperature and salinity

3.1 Instrument

Seabird thermosalinograph

3.2 Raw data

One minute averages
date and time UTC
quality indicator
mean temperature at the inlet
mean temperature at the probe
mean conductivity
mean salinity
turner fluorometer outputs (2) and spare channels (2)
number of samples for the current minute

3.3 Data Processing Procedures

Surface values of sea temperature and salinity for each CTD station are compared with the thermosalinograph values. An offset is then applied to the sea surface temperature and salinity.

The following offsets were used:
Salinity 0.034
Temperature -0.008

3.4 Data Coverage

02:15 26-sep-2000
01:20 12-nov-2000

The following data were rejected

TABLE 1.

Start	End	salinity/temperature or both	Comments
02:15 26-sep-2000	06:44 26-sep-2000	s	before bubbling problems corrected
14:01 26-sep-2000	14:04 26-sep-2000	s	
05:00 27-sep-2000	04:00 28-sep-2000	leave in	warning - “spikey” salinity data
22:30 29-sep-2000	22:30 29-sep-2000	s	
14:09 01-oct-2000	14:12 01-oct-2000	s	
00:24 05-oct-2000	00:34 05-oct-2000	b	
20:59 10-oct-2000	20:59 10-oct-2000	s	
11:27 11-oct-2000	11:27 11-oct-2000	s	
11:45 13-oct-2000	11:45 13-oct-2000	s	
13:16 20-oct-2000	13:16 20-oct-2000	s	
15:37 20-oct-2000	15:37 20-oct-2000	s	
22:26 20-oct-2000	22:26 20-oct-2000	s	
22:50 20-oct-2000	22:50 20-oct-2000	s	

3.5 Data Quality

The CTD salinity values should be within .003 resolution, and the CTD temperature within .003 degrees; the thermosalinograph only records to the second decimal place so the best precision would be within .01 psu for salinity and .01 degrees for temperature.

Bubbling problems which cause spikey salinity data were corrected on 06:44 26 September. Salinity data up till that time has been rejected.

Fluorometer data is not a standard product.

4. Other

4.1 Hourly file naming convention

eg fr01079a00.tsg
vvyynnnhmm.int

where vv is vessel where fr - franklin
yy - year
ddd - day through year
a - hour through day a- 00; b 01 ... x 23
mm - 00 minute at start of file - usually files are started every hour - but if logging is restarted minute of restart
tsg - thermosalinograph

4.2 Printed material

Printed materials created during the processing are available from the Data Centre (Terry Byrne).

4.3 Date and Times

All dates and times are in UTC unless otherwise stated.

ADCP Data Processing Notes

1 Features of this voyage

Initially the maximum depth of useable ADCP data was typically 400 m (in deep water) which is expected with the narrow-band ADCP on the Franklin. The range deteriorated and by 8 Oct the range was about 220 m with some deep isolates. By the 20 Oct the range was unstable and shallow; the instrument was raised out of the water for examination on 31 October and then not used. A fault in the ADCP connectors was subsequently corrected on the following voyage. There was only 2% bottom track coverage.

The Ashtech 3DF GPS was operating during this cruise. It's highly accurate values of the ship's heading, pitch and roll were used to determine the absolute water velocities; producing 95.6% possible coverage. Values of ship's heading from the ship's gyrocompass were not used in the processing.

Differential GPS was operational at all times during this voyage, but unexplained small gaps in the data occurred.

2 Special Processing For This Cruise

Only3DFship'sheadingandnogyrocompassheadingswereusedfordataprocessingusing the 3 minute .adp files returned from the voyage. Direct velocities were used in preference to position derived GPS velocities. All data after 01:40 30 October have been rejected.

2.1 Profiles integrated

Bottom track corrected, no reference layer averaging in final integration: fr0009_3df.abt: 48 20 minute profiles (2% or voyage)

Best available correction (Bottom track preferred to direct GPS velocities, preferred to position derived velocities): fr0009_3df.any: 2331 20 minute profiles fr0009_3df_60.any: 785 60 minute profiles

Non-integrated profiles (3 minute ensembles):

All possible ensembles with best available correction (bottom track preferred to direct GPS velocities, preferred to position-derived GPS velocities). e_f0009_3df.any: 15426 3 minute profiles

The following files were first integrated using reference layer averaging over bins 2 to 8, then merged with files which were integrated using no reference layer averaging.

GPS corrected (direct GPS velocities preferred to position-derived velocities): fr0009_3df.agp: 2331 20 minute profiles fr0009_3df_60.agp: 785 60 minute profiles

NB: See ADCP Format Guide for explanation of processed file formats.

3 Data Rejections

Out of a total of 15798 three minute ensembles, 15426 made it through to the processed file stage, with 364792 total good bins.

Bin 1 rejections 661

Number of bins rejected due solely to:
- %Good < 30%: 201597
- %Good < 50%: where RLA was bad and no acceleration: 4325
- %Good < 70%: where RLA was bad and there was acceleration: 217
- Vertical Velocity > 0.22 m/s : 2196
- S.D. of error velocity > 0.13 m/s: 3842
- Absolute Velocity > 2 m/s: 0
- Isolates: 713
- dv/dz shear per metre in upper 200 m > 0.10 m/s : 12

Number of bins rejected due to multiple tests: 192349

NB: this larger ejection of bins is most likely rejections at depth overall (as obviously entire ensembles weren't rejected). The faulty connectors have thought only to effect the range of the profiles; i.e. the accuracy of the remaining vectors should not be effected.

4 Calibration

ADCP water profile vectors (measured relative to the ship) are calibrated by being rotated through an angle alpha and multiplied by scaling factor 1 + beta. The rotational calibration primarily corrects for misalignment of the transducer with respect to the ship, of the ship with respect to the gyrocompass (or 3DF GPS), and the error in the gyrocompass (or 3DFGPS). The scaling multiplier primarily corrects biases arising from the profiler itself. Both of these calibrations make a large difference to the resultant currents, particularly because they are both applied to the usually large ship-relative currents. For example, a scaling multiplier of 0.01 applied when the water velocity with respect to the ship is 6m/s alters the measured absolute currents by 6 cm/s.

The following calibrations were chosen for this voyage.

alpha = 0.730 +/- 0.3 degrees
1 + beta = 1.0096 +/- 0.005

5 Errors

The data provided should not be taken as absolutely true and accurate. There are many sources of error, some of which are very hard to quantify. Often the largest error is that of determining the ship's actual velocity.

5.1 Accuracy of water velocity relative to the ship

The theoretical approximate short-term velocity error for our 150kHz narrow-band ADCP is:

sigma = 1/(pulse length X square root of pings per average)

For a 3 minute ensemble with say 170 pings, using 8m pulse, this gives a theoretical error of 1 cm/s for each value (that is, independently for each bin).

For 20 minute profiles, with say 1150 pings averaged, the error in measuring the velocity of the water relative to the ship is probably reduced to the long term systematic bias. Of this bias, RDI says

> "Internal bias is typically less than 1 cm/s, depending on several factors including temperature, mean current speed, signal/noise ratio, beam geometry errors, etc. It is not yet possible to measure ADCP bias and to calibrate or remove it in post-processing."

In addition, there are the transducer alignment and attitude sensor errors, which mainly cancel out where bottom-track ship velocities are used (see Section 5.3). For GPS ship velocity corrected currents, the transducer alignment and attitude sensor errors probably have a residual effect after calibrating of roughly:

0.3 cm/s per m/s of ship speed, due to, say, 0.3 degree uncertainty and variation in alignment angle.

0.5cm/s perm/sofshipspeed,dueto,say,0.005uncertaintyandvariationinscaling factor.

This gives us, say, 0.58 cm/s error per m/s of ship speed, or3.6 cm/s at 12 knots.

Other sources of bias might be the real-time and post-processing data screening, and depth-dependent bias.

5.2 GPS profiles

In the presence of SA (see sections 1 and 3), errors are larger and even very large errors cannot be removed by dv/dt screening (because this would bias the long term average - there is reason to assume that given a long enough period the accumulated SA error is close to zero).

5.3 Bottom track profiles

Firstly note that errors incurrent speed arising from transducer alignment and attitude sensor limitations will substantially cancel out. Normally ,the accuracy of screened bottom track data appears to be of the same order of accuracy as non-SA GPS, that is, about 2 - 3 cm/s for a 20 minute profile. However, the error in the current direction is at least the error in alpha.

CTD Processing Notes

Data processing completed by Bob Beattie

1. Summary

These notes relate to the production of QC'ed, calibrated CTD data from R V Franklin voyage Fr 09/2000 (26 Sept - 12 Nov, 2000)

Data for 142 stations was acquired using a Seabird SBE911 CTD unit fitted with a 24 bottle rosette sampler. Pressure and temperature were calculated using the Seabird-supplied calibration factors and the data was subjected to automated QC to remove spikes

The laboratory salinity determinations from the first part of the voyage were of less than ideal quality for performing conductivity calibration. The laboratory salinities for deployments 78 - 143 were of high quality and gave a calibration standard deviation of 0.0022 psu. This calibration was also applied to the remaining deployments. We consider this approach to be justified, as the laboratory analyses and a comparison of the output of the primary and secondary conductivity sensors revealed little, if any, long term sensor drift during the voyage.

Dissolved Oxygen was calibrated by fitting the data to an Owens and Millard (1985) model of the Beckman-style oxygen sensor. It is apparent that this model does not quantify all factors affecting the sensor output, which means that the CTD oxygen values should only be used for qualitative interpretation.

2. Voyage details

2.1 Title

Monitoring Ocean Climate Change around Australia. The Deep Ocean Time-series Sections

2.2 Principal Investigators

Susan E Wijffels & John A Church , CSIRO Marine Research, Hobart & Nathan Bindoff, Antarctic Co-operative CRC, University of Tasmania, Hobart

2.3 Voyage objectives

The voyage summary states that the purpose was to reoccupy portions of several WOCE hydrographic lines between Australia and longitude 95E as part of establishing a deep-ocean time series section grid around Australia. For further details are contained in the voyage summary (http://www.marine.csiro.au/franklin/plans/fr0900s.html).

2.4 Area of operation

See Figure 1

3. Processing Notes

3.1 Background Information

The data was acquired with CSIRO's CTD unit #20, a Seabird SBE911 with dual conductivity and temperature sensors, an SBE13B, 'Beckman' dissolved oxygen sensor and a 24-bottle rosette.

The raw CTD data was converted to scientific units and written to netCDF format files for processing using the matlab-based, procCTD package. procCTD is described in the procCTD User's Manual.

procCTD applies automated QC and preliminary processing to the data. This includes spike removal, identification of water entry and exit, conductivity sensor lag corrections and the determination of the pressure offsets. It also loads the hydrology data and computes the matching CTD sample burst data.

The conductivity and dissolved oxygen calibrations were then computed and applied to the data and the files of binned, averaged data were produced.

3.2 Pressure and temperature calibration

Pressure and temperature were computed using the Seabird-supplied calibrations.

An additional pressure offset correction was computed for each deployment by assuming a linear drift between the pre and post-deployment, out-of-water pressures. The pressure offsets for the voyage are plotted in Figure 2, below. The pressure sensor shows slight hysteresis in its response, with the out-of-water offsets for the deeper deployments being about 0.4 dB greater than the in-water offsets.

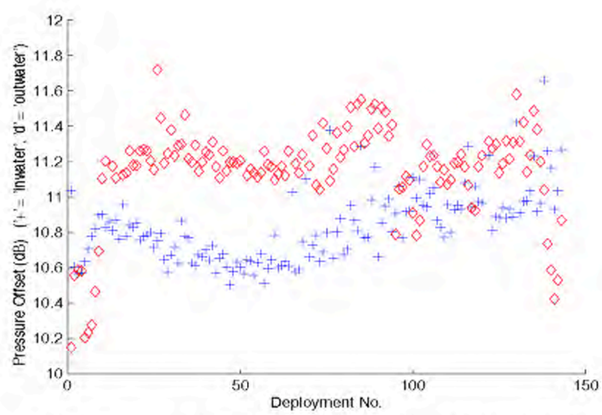

Figure 2 **Pressure Offsets, deployments 1-120, 122-143**

The mean outputs of the primary and secondary temperature sensors generally agree within 1.9 +/- 0.3 mDeg C (Fig 3)

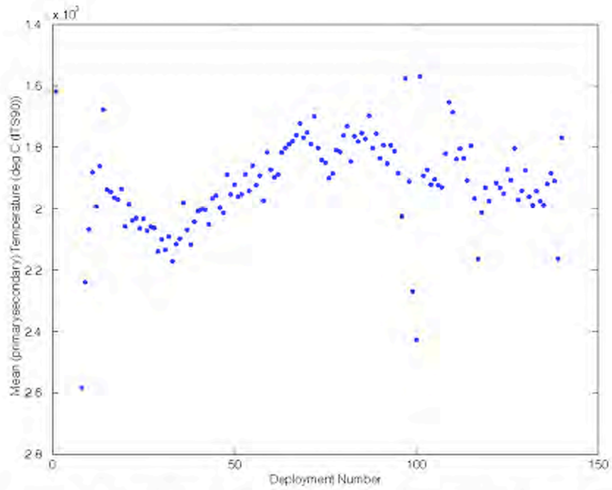

Figure 3 Mean Difference, Temperature sensors, P > 1000 dB

3.3 Conductivity calibration

Salinometer problems were experienced during the first leg and early part of the second leg of the voyage, as can be seen from the scatter in the *(CTD-bottle) Conductivity* plot (Fig 4)

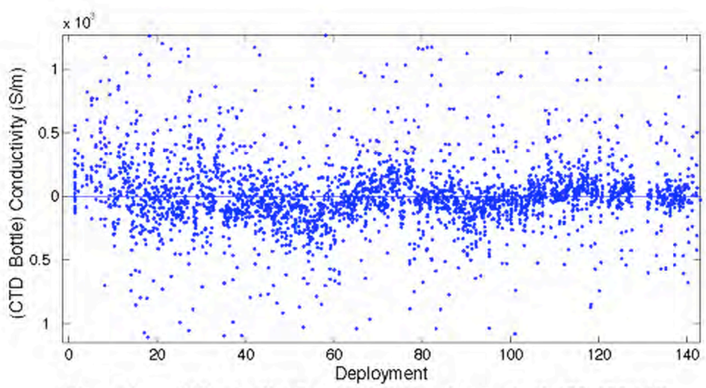

Figure 4 (CTD - bottle) Conductivity, Deployments (1-120, 122-143)

After consultation with Steve Rintoul, we decided to use the calibration for deployment 78 onwards to calibrate the whole voyage. The reasoning for this was that:

1. The salinometer problems had been resolved from deployment 78 onwards, as evidenced by the much-reduced reduced scatter in the difference plot (Fig 4).
2. Fig 4 and the plot of *Mean (Primary - Secondary) Conductivity* (Fig 5) suggest that the sensor calibrations did not change significantly during the voyage.

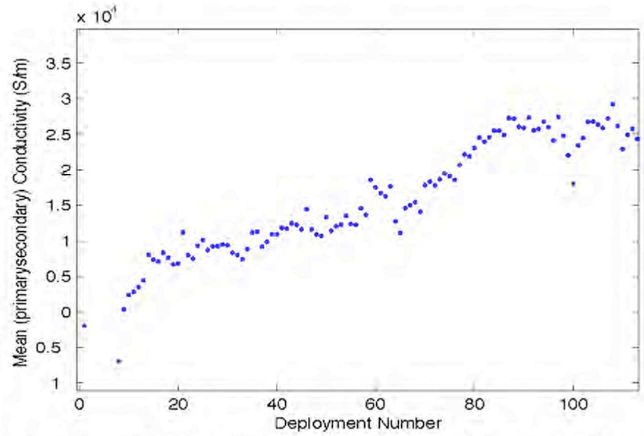

Figure 5 Mean (primary-secondary) Conductivity for P > 1000 dB

The difference between the primary and secondary CTD conductivity cells was essentially zero at the start of the voyage and had increased to only 0.0003 S/m by deployment 113. (The secondary cell became unserviceable after it developed a crack in its glass electrode during deployment 114.)

The procCTD calibration procedures differs from our old (pre procCTD) procedures in that

- The calibration is applied in addition to the Manufacturer's Calibration, rather than being applied to the raw data.
- No allowance is made for inter-deployment drift.

The calibration for deployments 78 - 143, with no sample data explicitly flagged as *Suspect* or *Bad*, but using procCTD's *Exclude Outliers* option, gives the following calibration factors:

Scale Factor (a1) 1.0001923 w.r.t. Manufacturer's calibration
Offset (a0) 1.17496E-04 ditto
Calibration S.D. (Sal) 0.002203 psu

3.4 Dissolved Oxygen Sensor Calibration

Our model for the response of the Dissolved Oxygen sensor is based on Owens and Millard (1985). It uses an iterated, 6-parameter fit for the parameters:

Oxygen Current Slope
Oxygen Current Bias
Sensor Lag
Activation Energy
Reaction Volume
Temperature weight

In principle, the last 4 factors should be constant for the sensor type and geometry, with only the Slope and Bias changing, as the sensor becomes depleted. In practice, we iterate some or all of the other components, as we have not yet determined the ideal default values.

In addition, the sensor model does not take account of all factors affecting the sensor output. as there seems to be an additional hysteresis effect that allows only one, rather than both, of the downcast and upcast sensor outputs to be matched to the bottle data. (The 'downcast samples' are the downcast values for the same pressures as the 'Upcast sample bursts.)

For fr0009, I adopted the following strategy:

1. The default *Reaction Volume* and *Temperature Weight* were assumed to be correct
   Reaction Volume -29.6
   Temperature Weight 0.9
2. The same oxygen sensor was used for the whole voyage, so it was possible to perform a whole-of-voyage iteration, calibrating the bottle data against both the down and upcast CTD ‘sample burst’ data. The Reaction Volume and Temperature Weight were left fixed and values were computed for the other four parameters.
3. The *Lag* and *Activation Energy* were fixed at the values determined from the whole-of-voyage iteration:
   Sensor Lag 7.8681
   Activation Energy 4611.6
4. The deployments were arbitrarily divided into 4 groups of sequential deployments, to reduce the effect of sensor depletion, and values of slope and bias were computed by calibrating the bottle data against the downcast ‘sample bursts’.

Deployment grouping	*Current Slope*	*Current Bias*	*Fit S.D. (uMole/l)*
1-35	4.2217E-04	-3.7086E-03	5.2162
36-70	4.3017E-04	5.6643E-04	3.7585
71-100	4.0114E-04	-4.946E-03	3.7112
101-143	4.0253E-04	-2.259E-03	2.4792

This produces a reasonable agreement between the bottle data and the downcast profile, but it is by no means perfect. There was an unexpected 7% increase in sensitivity occurred somewhere between deployments 36 and 100. As far as I know, the same DO sensor was used for the whole voyage. You would have expected the *Current Slope* (gain) to progressively increase as the sensor reagents become depleted, but this is obviously not the case.

Two typical downcast profiles are shown in Fig 6.

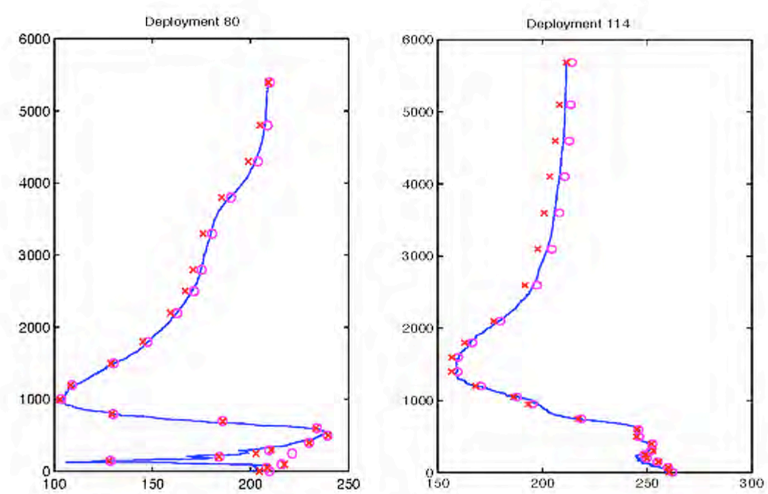

Figure 6: Downcast CTD oxygen + bottle oxygen (o) & upcast oxygen (x) (uMole/l)

The calibrated oxygen data should only be used for qualitative and semi-quantitative work. It is as good a fit as can be expected, given the limitations of our current understanding of the oxygen sensor model.

3.5 Other sensors

No other CTD sensors were logged during this voyage.

3.6 Binned data files

The calibrated data was 'filtered' to remove pressure reversals and binned into 2dB averaged netCDF files. The binned values were calculated by applying a linear, least-squares fit to the bin data and using this to interpolate the value for the bin mid-point. This is more accurate than simply taking the mean of the data.

Each bin is assigned a QC flag for each binned parameter. Our flagging scheme is described in **http://www.marine.csiro.au/datacentre/ext_docs/DataQualityControlFlags.pdf**.

The QC Flag for each bin is estimated from the values for the bin components. (We haven't yet documented this. For the moment, refer to the comments in matlab function **matlab/toolbox/local/dpg/util/@QCFlag/estimate.m** (or '*help estimate*').) The QC Flag for derived quantities, such as Salinity and Dissolved Oxygen is taken to the worst of the estimates for the parameters from which they are derived.

4. References

Beattie, R.D., in prep, procCTD CTD Processing Procedures Manual. FrameMaker document /net/fdcs/opt/fdcs/src/ctd/doc/procCTD.fm

Owens, W.B, and J.C. Millard Jr., 1985: A new algorithm for CTD oxygen calibration. J. Physical Oceanography., 15, 621-631.

Pender, L., 2000: Data Quality Control Flags. http://www.csiro.marine.au/datacentre/ext_docs/DataQualityControlFlags.pdf

Hydrology Processing Report

Data processing completed by Rebecca Cowley, 1 November, 2001

1 Summary

These notes relate to the production of calibrated hydrology data for the *RV Franklin* voyage Fr0009. Salinity, dissolved oxygen and nutrient data was processed. 143 deployments were completed, of which 138 have valid data.

2 Voyage details

The following information is taken from Voyage Summary Fr0900.

2.1 Chief scientist

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CSIRO Marine Research

Nathan Bindoff
Antarctic Co-operative Research Center
University of Tasmania

2.2 Voyage objectives

To reoccupy portions of several WOCE hydrographic lines between Australia and 95° E in the southeast Indian Ocean as part of establishing a deep-ocean time-series section grid around Australia. Full-depth 24 bottle 5L Niskin/CTD casts will be taken at WOCE spatial resolution. Sampling and chemical analyses will be completed for salinity, oxygen, nutrients, dissolved carbon and alkalinity. At-sea quality control will occur with all CTD and sample data collected and scrutinized as soon as it is available and compared with the WOCE data.

2.3 Area of operation

See Figure 1

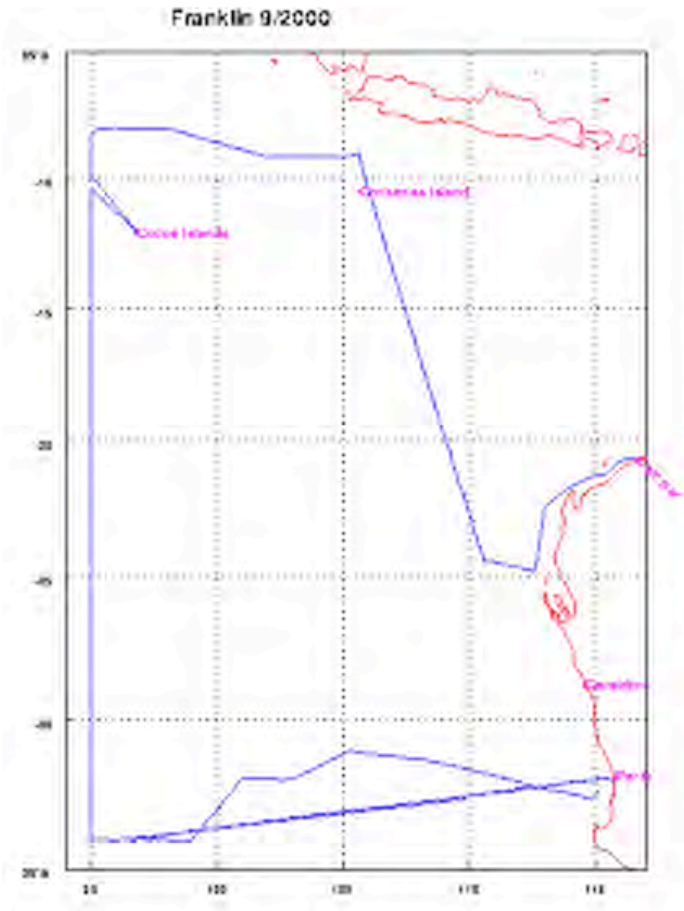


Figure 1 Voyage track

3 Processing notes

3.1 Introduction

The hydrology data was processed according to the procedures outlined in “Hydrology data processing procedures”, First edition, Rebecca Cowley.

Hydrology data is collected on the upcast of a CTD deployment, and salinity data is compared to calibrated CTD upcast burst data. Erroneous values are deleted from the dataset. Dissolved oxygen and nutrient data are compared deployment to deployment, with obvious outliers deleted from the dataset.

CTD unit #20 was used on this voyage and 143 deployments were completed, of which 138 contain hydrology data. Deployments 121, 128 – 130 and 132 do not contain hydrology data. Salinity, dissolved oxygen and nutrient data were collected.

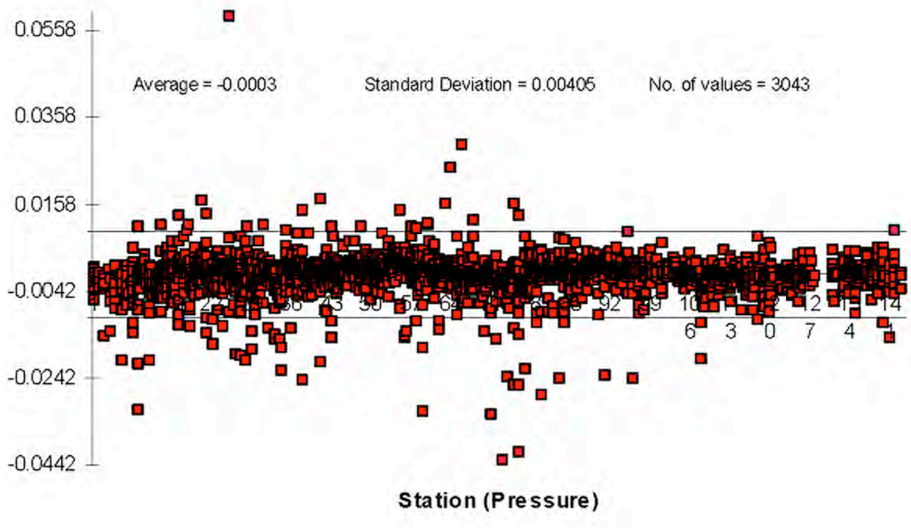
3.2 Salinity

Salinity data deleted from the dataset are shown in Table 2. All deletions were due to a bad sample or analysis. Many outliers were retained and can be attributed to the surface water structure which leads to anomalies between the CTD and hydrology data. The area of sampling had surface water with steep haloclines. The final CTD salinity – Hydro salinity offset plot is shown in Figure 7.

Table 2: Salinity measurements deleted from hydrology dataset.

Deployment	Rosette Position	Niskin bottle	CTD-Hydro salinity difference
4	6	5020	-0.015
8	4	5022	-0.013
15	21	5014	-0.02
17	2	5009	0.013
17	18	5016	0.013
20	15	5019	0.05
21	11	5001	-0.021
21	12	5055	-0.017
24	17	5017	0.015
24	20	5023	-0.011
24	21	5014	-0.016
27	4	5006	-0.011
29	11	5016	
30	23	5004	
34	13	5003	-0.03
39	20	5020	-0.2
40	11	5011	-0.035
42	11	5011	-0.036
44	22	5005	-0.022
45	22	5005	-0.014
46	22	5005	-0.012
47	22	5005	-0.017
50	14	5026	
50	22	5005	0.025
68	10	5021	0.032
69	10	5021	0.036
74	10	5021	-0.017
76	10	5021	-0.007
76	10	5021	0.053
76	18	5022	0.014
76	19	5004	-0.041
76	21	5003	0.013
76	22	5007	-0.026
77	10	5021	-0.007
85	21	5003	-0.173
90	7	5013	0.021
93	18	5010	-0.986
97	2	5019	-0.019
101	10	5009	-0.019
102	13	5013	-0.01
102	20	5006	0.013
104	11	5026	-0.073
109	16	5005	0.198
109	22	5008	0.023
120	14	5016	-0.01
122	18	5022	0.257
127	18	5010	-0.19
136	17	5021	0.788

Figure 7: CTD salinity – Hydro salinity final offset plot.



3.2.1 Data Quality

During the first leg of the voyage, problems were encountered with the salinometer, and more scatter in the data is apparent in the early results. Many results have been kept as the difference in bottle and CTD salinity may be due to the steep haloclines present in the top 500 metres of the deployment.

3.3 Dissolved oxygen

Table 3 lists the dissolved oxygen data points that were deleted from the dataset due to errors in analysis or sample collection.

Table 3. Dissolved oxygen measurements deleted from the dataset.

Deployment	Rosette Position	Reason for deletion
13	1	Dubious result
13	2	Dubious result
13	3	Dubious result
13	4	Dubious result
43	11 to 21	Dubious result
54	5	Bad sample or analysis
64	8	Bad sample or analysis
64	14	Bad sample or analysis
65	2 to 14	Incomplete records
69	10	Bad sample or analysis
74	10	Bad sample or analysis
75	4	Bad sample or analysis
76	10	Bad sample or analysis
77	10	Bad sample or analysis
77	13	Bad sample or analysis
82	1	Bad sample or analysis
82	5	Bad sample or analysis
88	19	Bad sample or analysis
109	1	Bad sample or analysis
134	4	Bad sample or analysis

3.3.1 Data Quality

The dissolved oxygen data quality for this voyage is good.

3.4 Nutrients

Due to contamination of the milli-q water supply, nitrate results for many runs were adjusted after the voyage. Below is a brief description of the corrections applied to the dataset. During the cruise it was noted that the Nitrate/Nitrite standard curve was giving a slight negative intercept. This negative intercept became more apparent as the cruise continued. The problem was traced back to the Milli-Q water system and changing all filters gave little improvement. Milli-Q water from a carbouy that had been loaded on at Hobart was used to make all the nitrate reagents and ASW carrier which instantly corrected the problem and the negative intercept was no longer evident. The duplicate samples from the affected runs were stored at Marmion for later analysis back at Hobart. Unfortunately there was a problem with the freezer at Marmion and all the samples thawed and were unfrozen for an undetermined time.

Back in Hobart:-

The theoretical recovery of the SRM's from the runs were calculated.
The percentage error appeared to give a linear correlation with concentration using SRM and QC samples.
The percentage recovery of samples from the runs were calculated against the SRM and QC recovery.
The correction used was:

(Uncorrected Value times 100) divided by (Percentage recovery of the low SRM + (Uncorrected Value minus Low SRM concentration) times (difference in percentage recovery between the low and high SRMs divided by difference in SRM concentrations))

Table 4 lists the data that was deleted from the dataset in the post-voyage processing and the reasons.

Table 4. Nutrient results deleted from the dataset.

Station	Rosette Position	Bottle	Reason for deletion
15	12	5005	All nutrients - sample taken from wrong bottle
18	6	5011	All nutrients - Sampling or analysis error
18	8	5026	All nutrients - Sampling or analysis error
21	9	5012	Silicate - Sampling or analysis error
37	12	5017	Nitrate - Sampling or analysis error
46	19	5013	Phosphate - Sampling or analysis error
68	9		All nutrients - Sampling or analysis error
69	10		All nutrients - Sampling or analysis error
69	All results		Nitrate - Sampling or analysis error
74	10		All nutrients - Sampling or analysis error
76	10	5021	All nutrients - Sampling or analysis error
77	10	5021	All nutrients - Sampling or analysis error
86	All results		All nutrients - Analysis error
87	All results		All nutrients - Analysis error
88	All results		Phosphate - Sampling or analysis error
91	20		Phosphate - Sampling or analysis error
92	3	5023	Phosphate - Sampling or analysis error

3.4.1 Data Quality

The nitrate/nitrite results are dubious for some casts due to the analysis problems during the voyage. Silicate and phosphate appear to be good, but no quality control report is available at this time.

4 Other

Niskin bottle numbers were altered from the 4-digit number to a three digit number for archiving purposes. The bottle numbers were originally '50XX' where '50' represents a 5 litre bottle and XX represents the rosette position. In the archive, the bottle numbers have had the '0' removed.

Copies of printed materials and further information can be obtained from the Data Centre (Terry Byrne or Rebecca Cowley).

Acknowledgments

We received excellent support from the Ship's officers and crew and the scientific staff. We thank them and the shore based support staff for ensuring the success of the cruise. A number of people at CMR put in significant effort prior to the cruise to design, install and test new systems to meet the demanding needs of this cruise. In particular we thank Ron Plaschke for his logistics support and overseeing the upgrading/installation of the new systems and Ian Helmond and the Workshop for their design and assembly. We also thank Chari Pattiaratchi, Chief Scientist of the following cruise, for accommodating the need to extend the cruise following the medical evacuation.

Susan Wijffels	John Church	Steve Rintoul
Chief Scientist	Cruise Leader Leg 1	Cruise Leader Leg 2

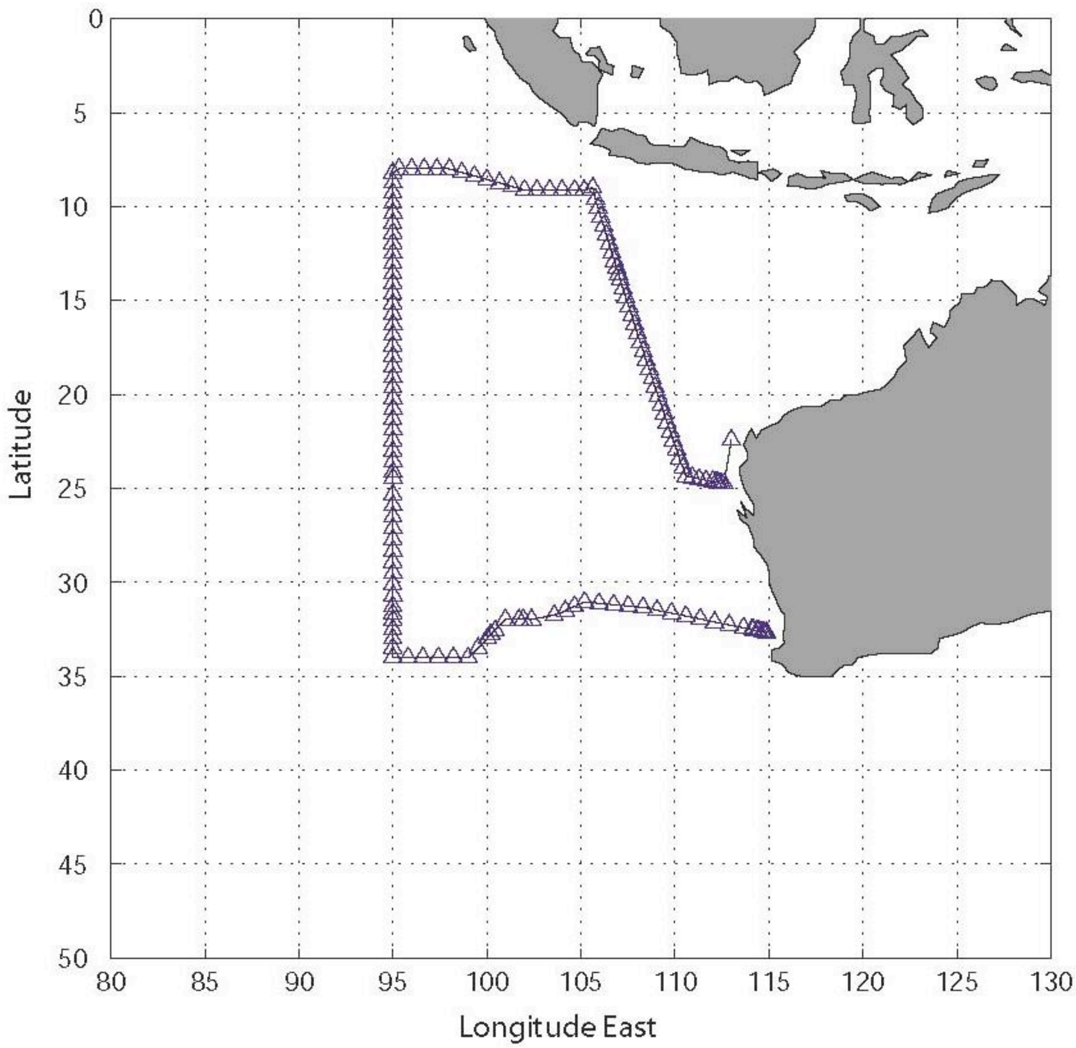


Figure 1: Hydrographic stations occupied during the cruise are indicated by triangles.

Appendices

Appendix A

Report on testing of XBT systems

The BOM system was tested with 14 XBTs over 4 CTDs. The XBTs all matched each other well and matched the CTDs with varying depth offsets of less than 2 or 3m. There appears to be a slight temperature offset but this is within 0.2 degC which is within the specifications for t-7 probes. No detailed analysis has been done but the data looks good and the system appears to work well. The data will be given to BOM who will do the detailed comparison after the CTD corrected data is available.

The Sippican system had problems from the beginning. The Sippican software had not been loaded before the computer was sent from Hobart. We installed the software, which apparently cause the computer to malfunction and run V E R Y slowly. Several days were lost trying to figure this problem out. We tried to re-install windows but the Windows 2000 system disks that had been sent were corrupted. Finally, Erik managed to fix the computer's hard drive and, at Rick's suggestion, we reloaded the Sippican system with the mk12 card installed. When we tried to launch a probe, the system couldn't communicate with the mk12 card because the "MK12IO.SYS" file was either missing or not working properly. We found the file and tried putting it various places but no luck. Given that it was installed (presumably properly and in the right place) by the Sippican installation, we have no idea why it didn't work. In the end, we ran out of CTDs and gave up. Steve Rintoul will be bringing a BOM windows computer with the Sippican program and mk12 card already installed to test on the second leg.

All credit to Erik Madsen for putting a LOT of time and effort into getting both systems up and (almost) running.

Appendix B

Indian Ocean nutrient data
Summary of corrections to the dataset

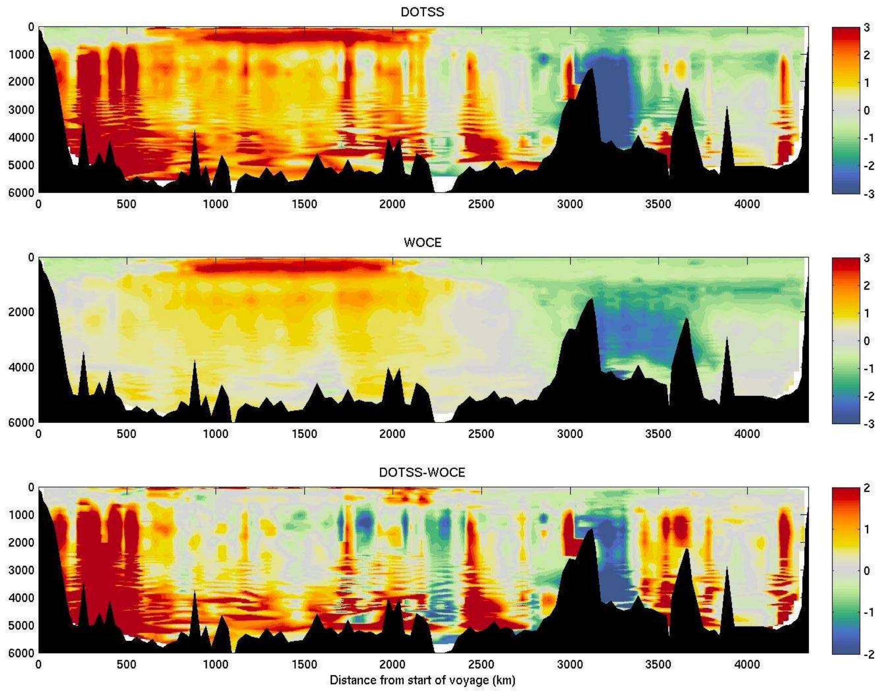
Introduction

During 2000, a Franklin voyage in the Indian Ocean was undertaken to repeat a WOCE section. The nutrient data on this voyage was collected using an Alpkem system. The results of the voyage compared with the WOCE section appear to have many run-based errors associated with them, and some bias in the phosphate results.

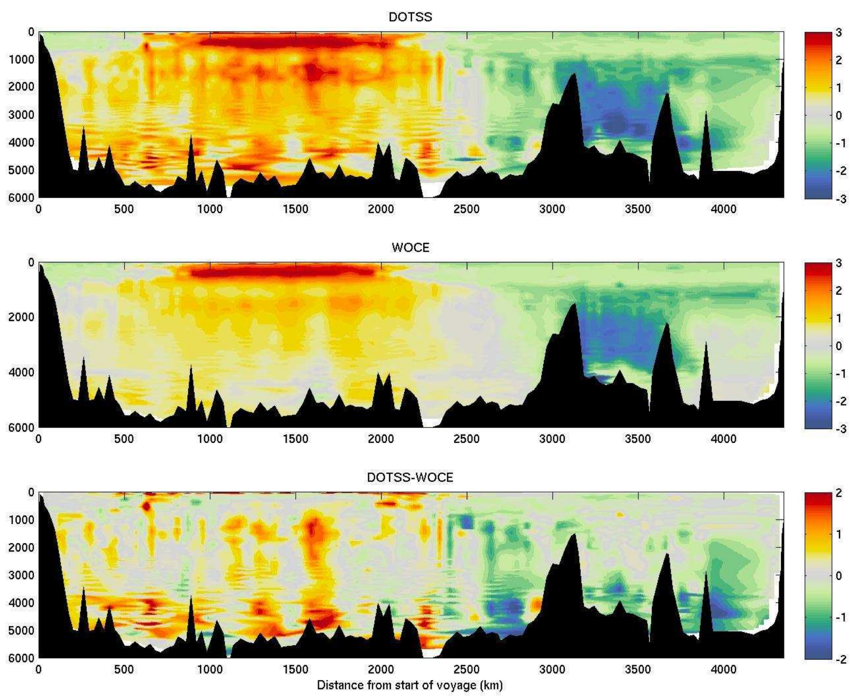
Below are some figures showing the comparison of the voyage data and WOCE data. In the first and second panels of each figure, data is compared to the mean WOCE data from between -10 and -50 latitude (ref). The calculation is the (concentration – ref)/standard deviation of the ref. In the third panels, the difference between the first two panels is shown.

All nutrient results are in um/kg and the nitrate results include nitrite.

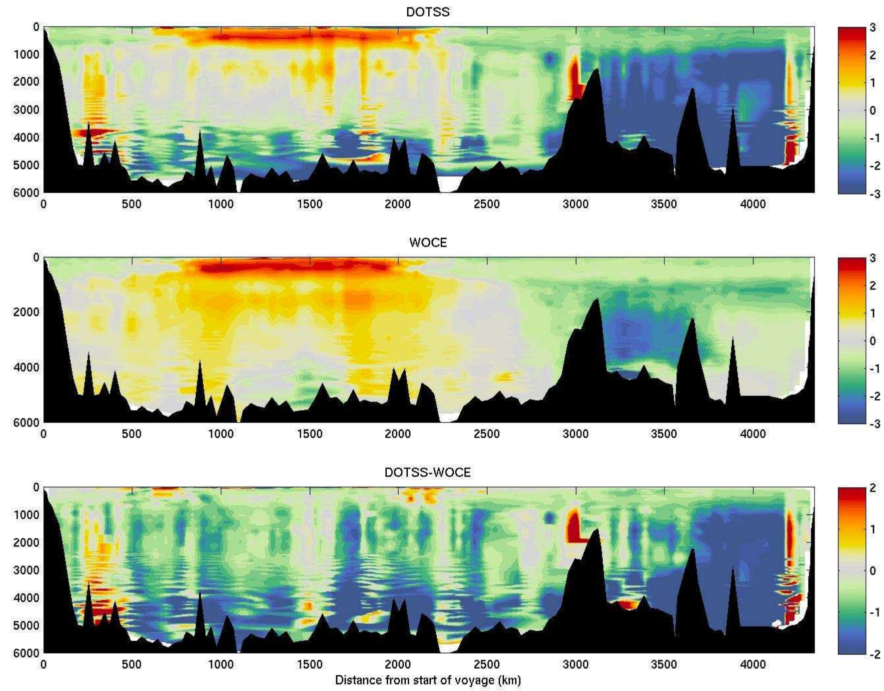
Nitrate: Original dataset.



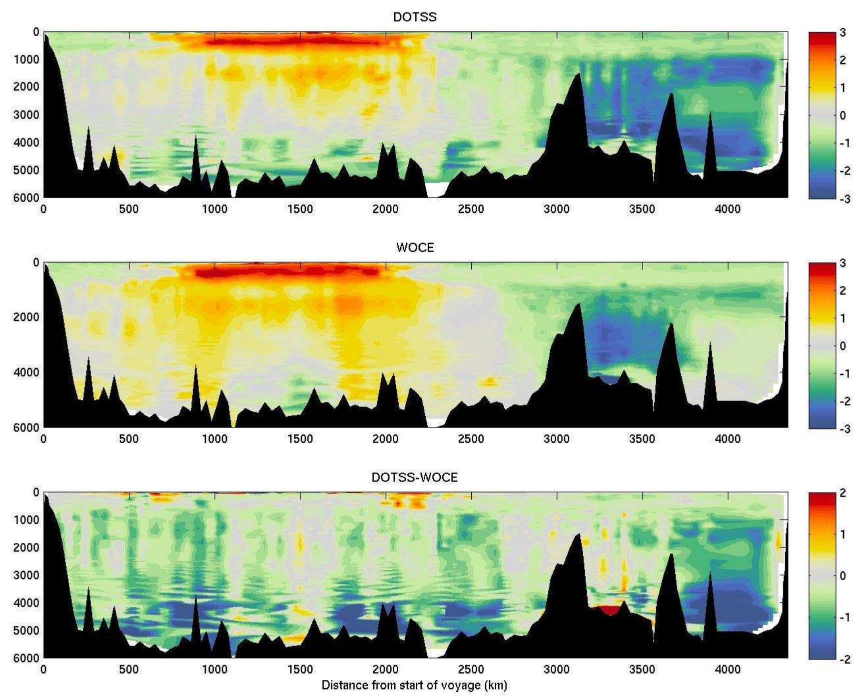
Nitrate: Dataset after re-processing.



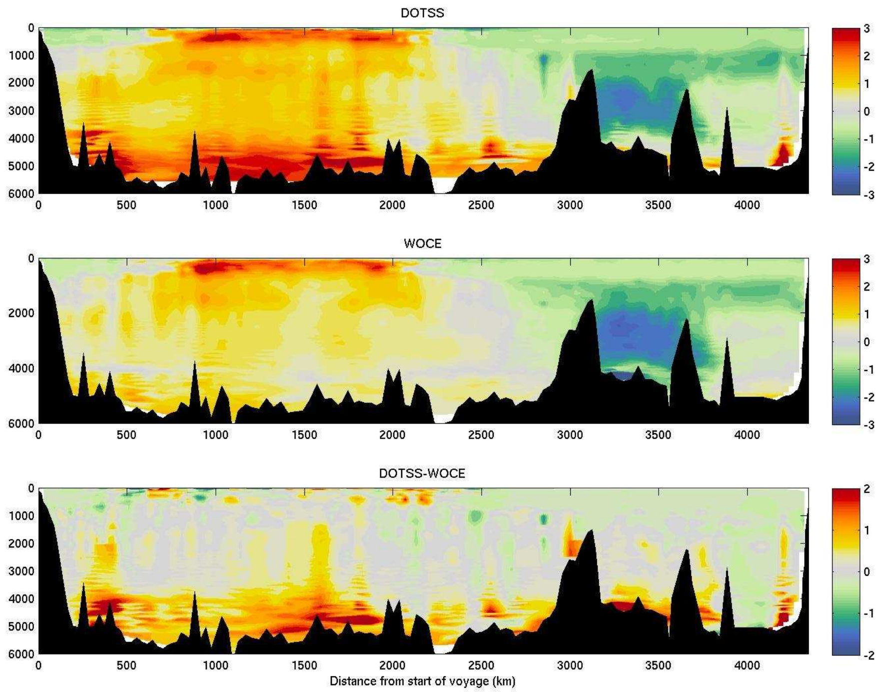
Phosphate: Original dataset.



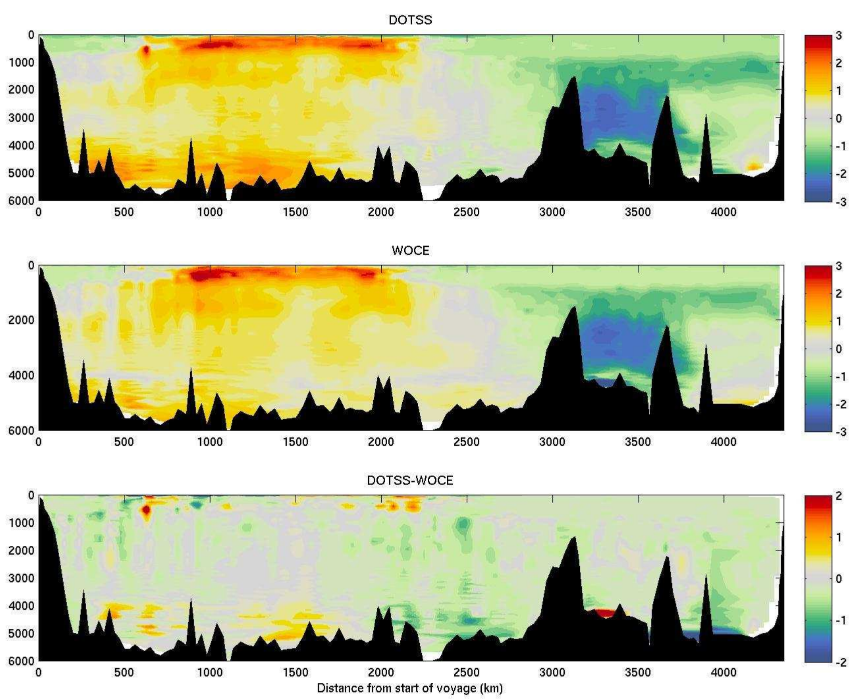
Phosphate: Dataset after re-processing.



Silicate: Original dataset.



Silicate: Dataset after re-processing.



Summary of corrections to the dataset.

The following corrections were made in order to improve the quality of the data:

1. The calibration of the data was re-done. The method outlined in the CSIRO Hydrochemistry manual was not used. Instead, calibration of the data was done using an adaptation of the WOCE Operations Manual method. The sensitivity factor of each calibrant was calculated, then the closest calibrant to the sample result was used to calculate the concentration. This initial step made a considerable improvement in the data.
2. The results were examined closely, and bad calibrants were removed from selected runs, some of the original run data was re-imported and some bad results were flagged bad in the dataset. A summary of all these alterations is given in Table 5.
3. A small section of nitrate was corrected based on QC sample results (runs 59 to 64), where there was a clear relationship between the QC results and the sample results. Unfortunately, the remainder of the dataset could not be corrected in the same way. The refractive index and blank values were averaged over the entire set of runs for nitrate and silicate, and these values used in place of individual run values. For phosphate, the refractive index and blank average for the first 49 runs was used in place of individual run values.
4. A final check of the results plotted against depth and potential temperature showed some bad results and these were flagged with a 4.

Conclusion

The final data has been corrected as best as possible. Further correction with SRM (standard reference material – OSI standards) data is not advisable, as there are errors associated with the make-up of these standards. The QC sample, which was bulk seawater sample that was autoclaved and then spiked, was included in every run. As this is a sample that is not diluted before a run, it is not subject to the same errors as the SRMs. The figures below show the QC sample results after the final corrections were made to the dataset. It may be possible to further correct the data based on the QC sample results, however, there does not appear to be any clear relationship between the observed difference from the WOCE results and the variation in the QC sample results.

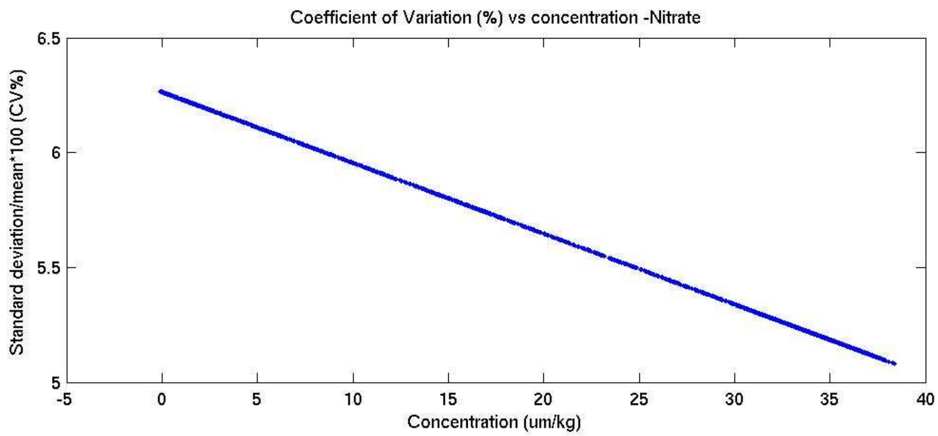
Estimation of precision:

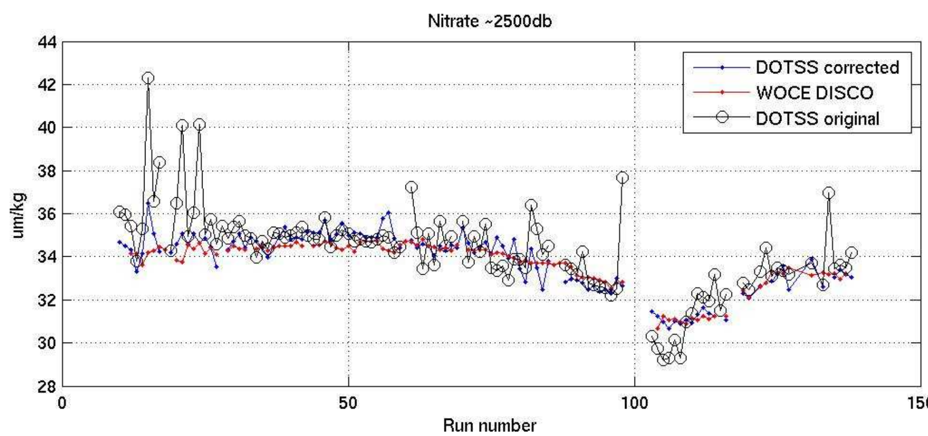
The precision of the results was estimated from the mean and standard deviation of the QC sample results from all runs. The mean coefficient of variation (CV% - standard deviation/mean*100%) for each nutrient is:

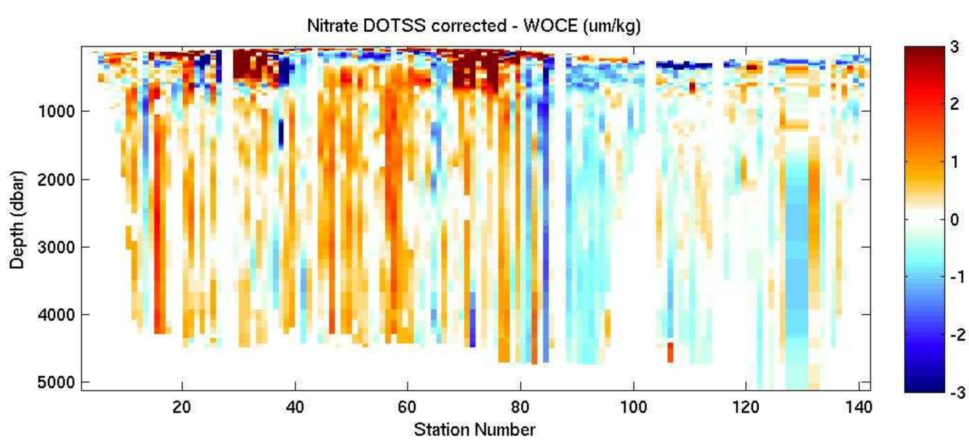
Nitrate/nitrite:	5.55%
Silicate:	1.5%
Phosphate:	3.55%

The plots below show a summary of the final results and the precision at each concentration.

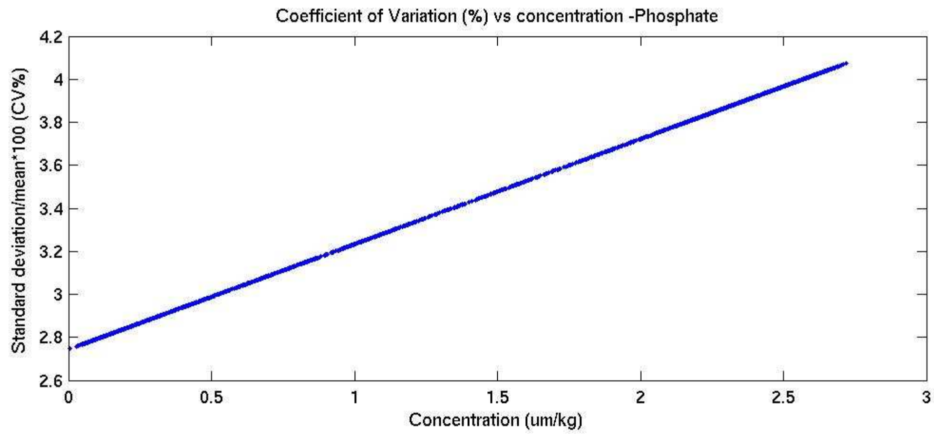
Nitrate final results:

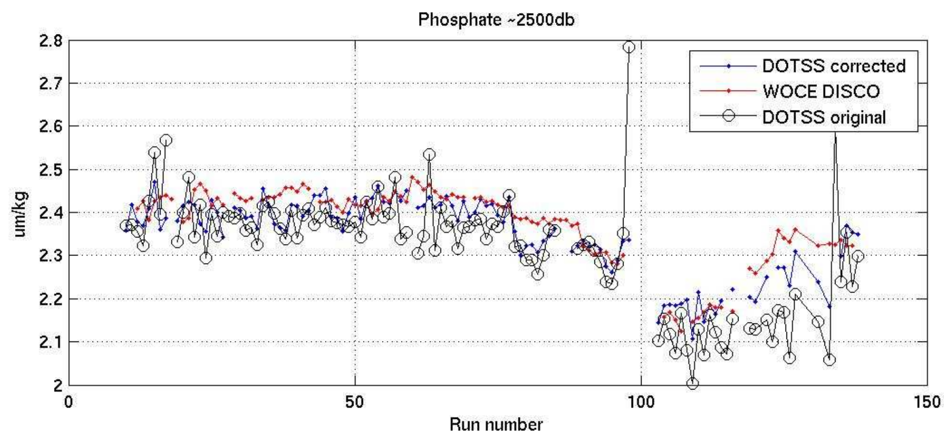


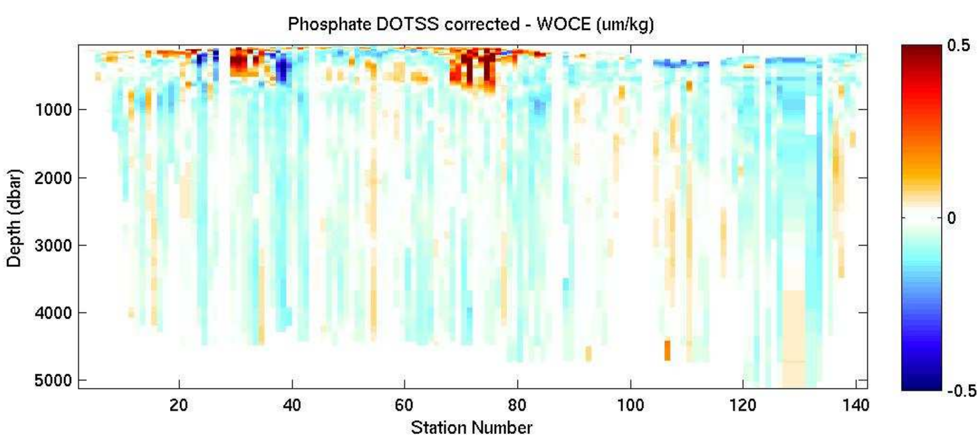




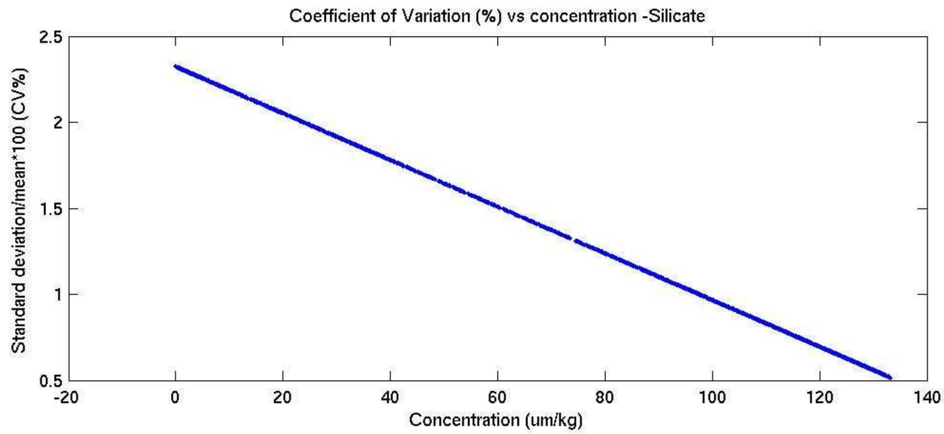
Phosphate final results:

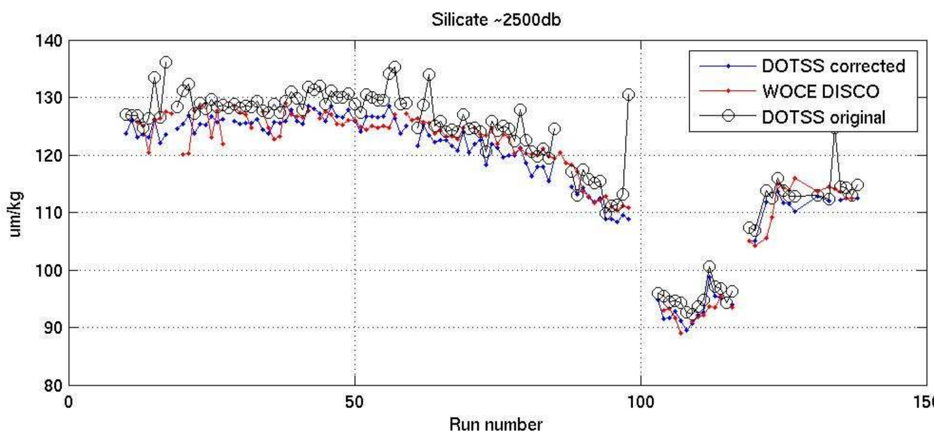


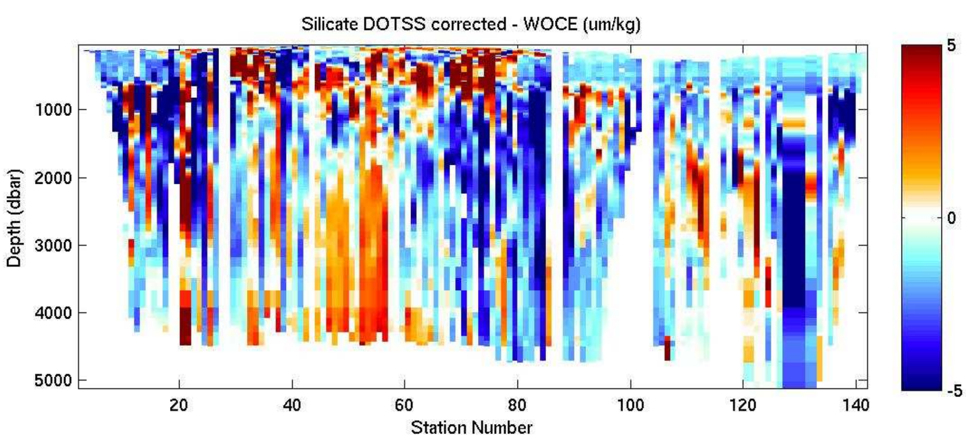




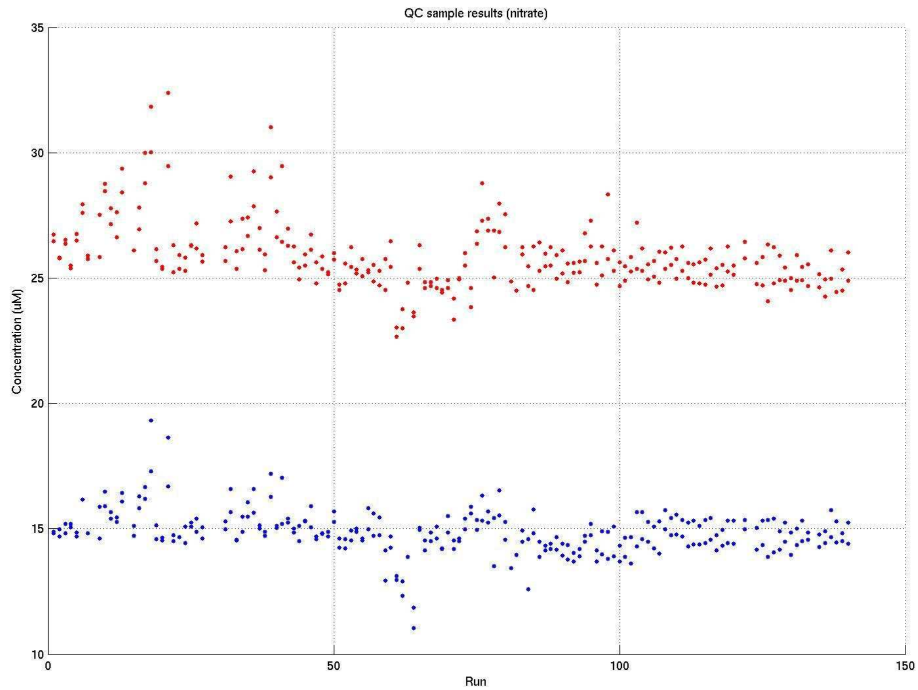
Silicate final results:

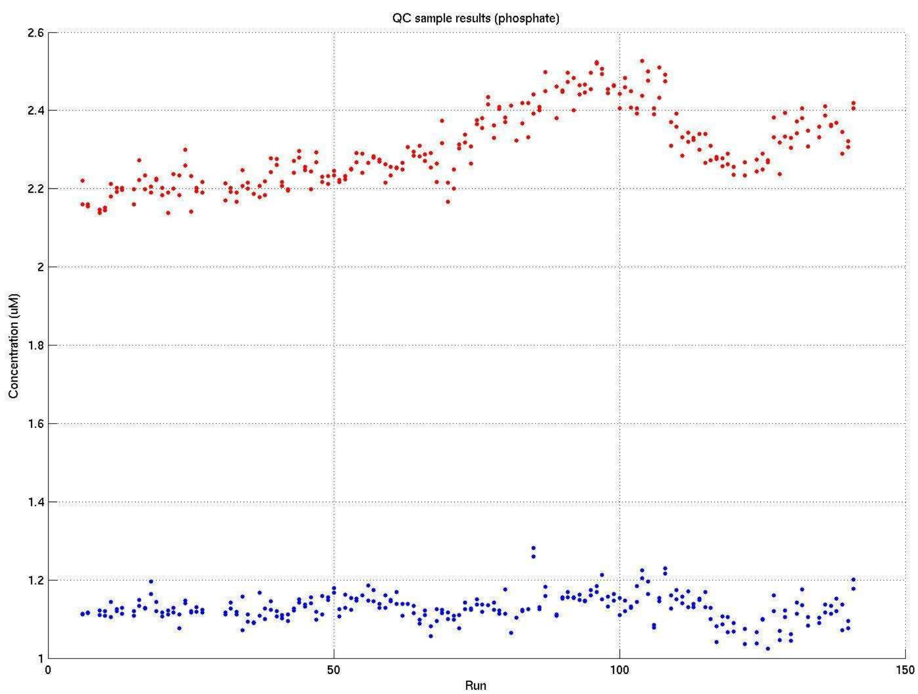


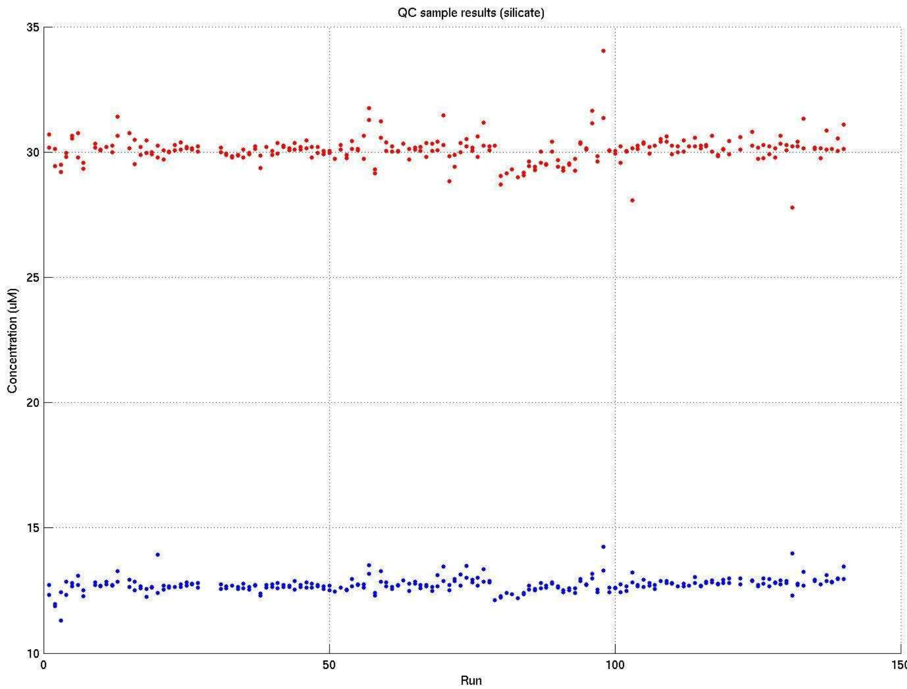




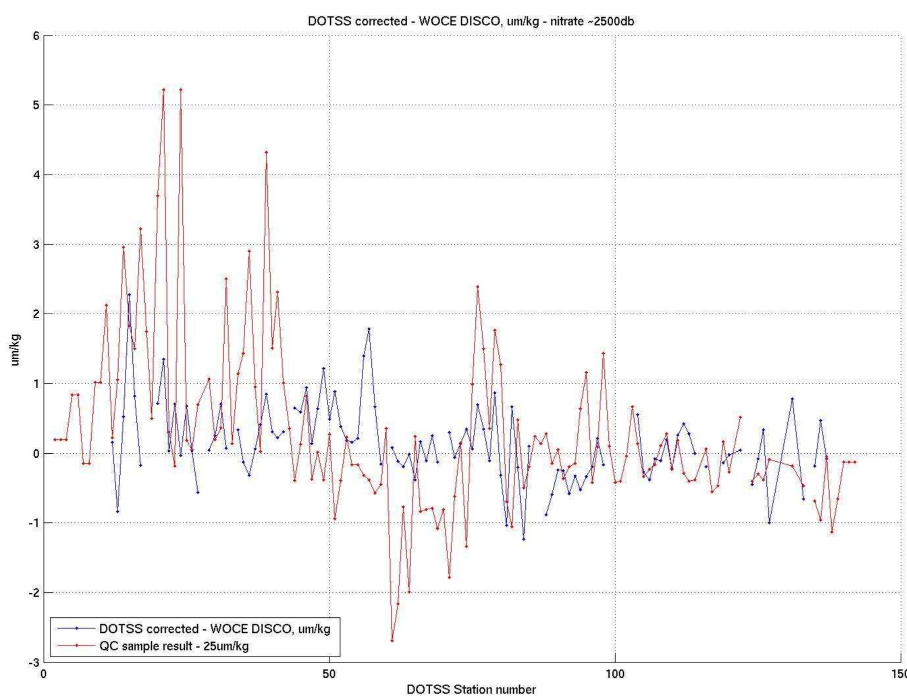
QC Sample results:

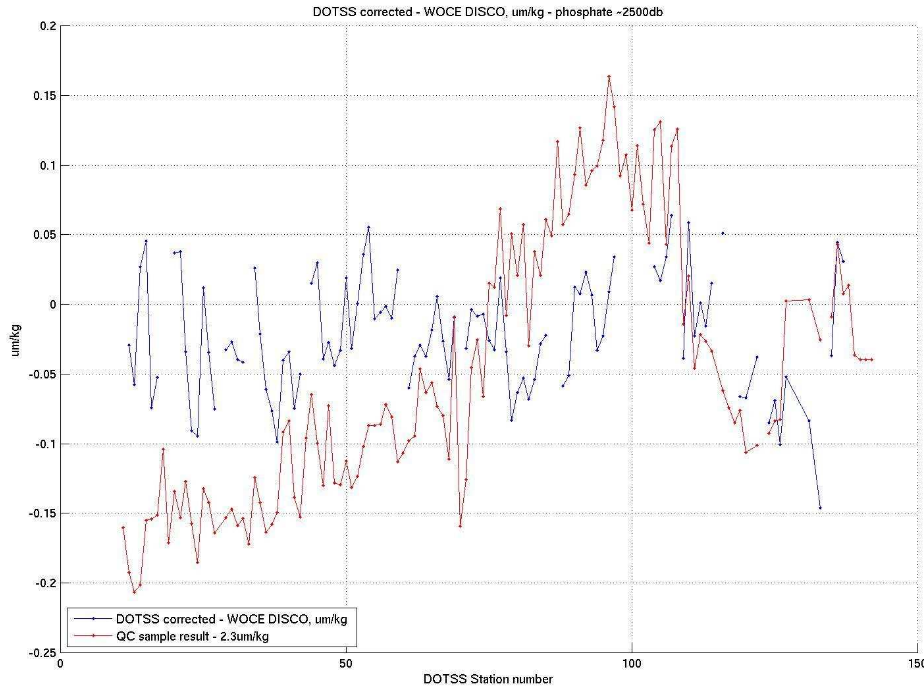




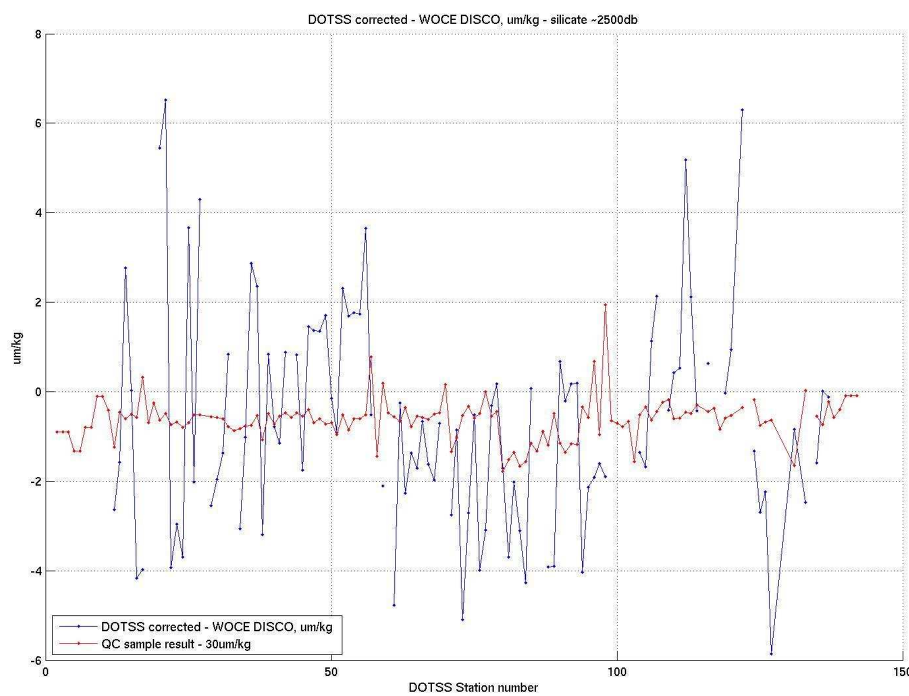


Mean QC Sample results and DOTSS-WOCE concentration at ~2500db



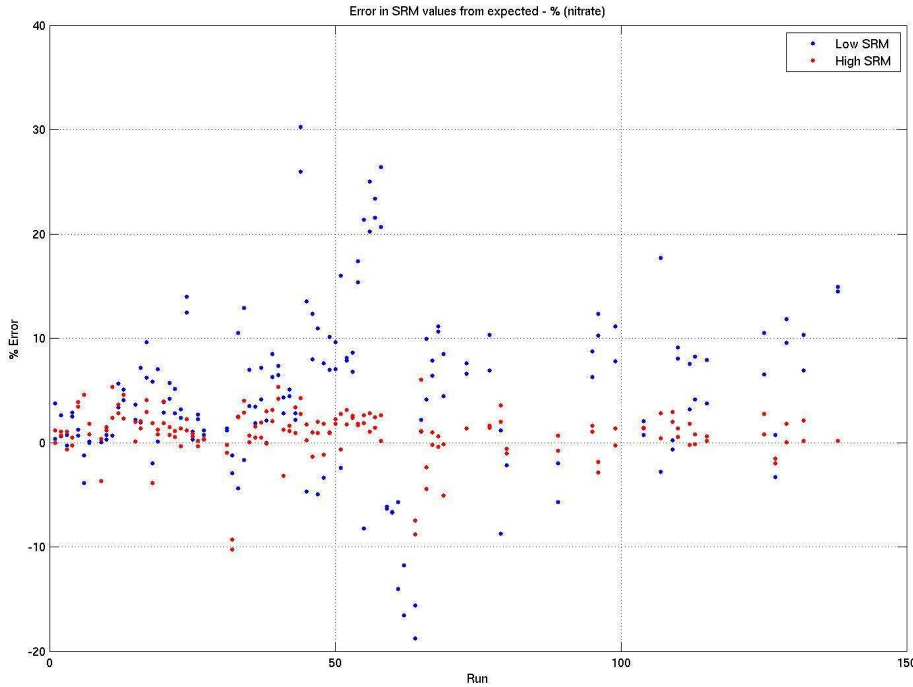


DOTSS corrected - WOCE DISCO, um/kg - phosphate ~2500db
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
um/kg
DOTSS corrected - WOCE DISCO, um/kg
QC sample result - 2.3um/kg
0
50
100
150
DOTSS Station number

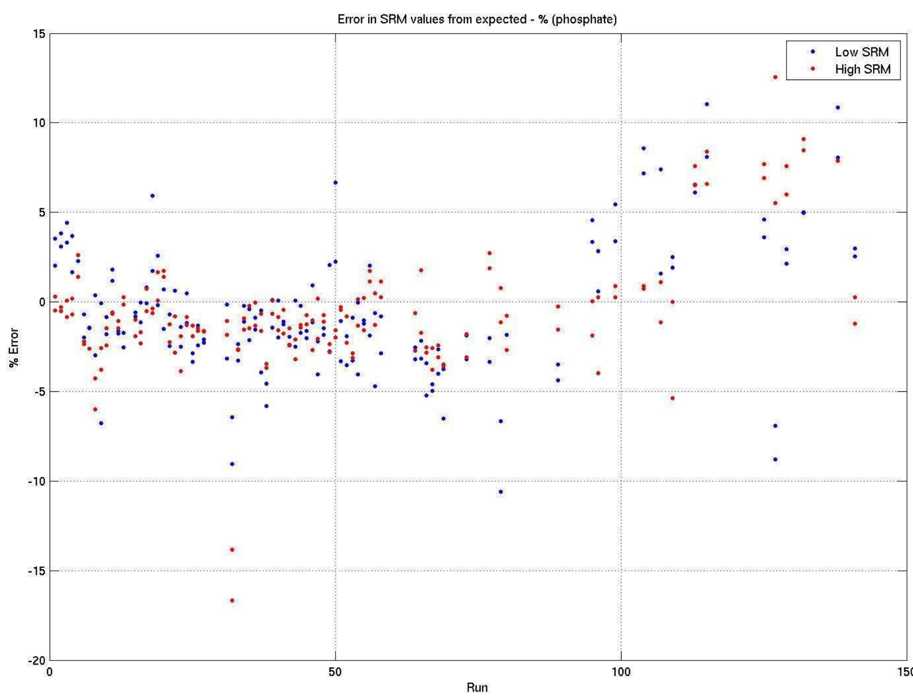


DOTSS corrected - WOCE DISCO, um/kg - silicate ~2500db
8
6
4
2
0
-2
-4
-6
um/kg
DOTSS corrected - WOCE DISCO, um/kg
QC sample result - 30um/kg
0
50
100
150
DOTSS Station number

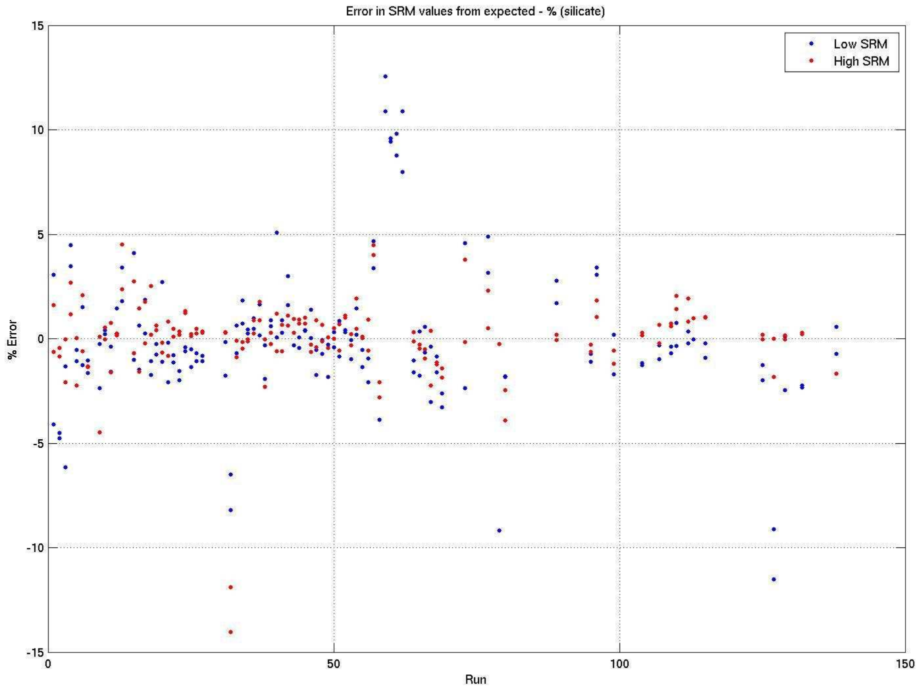
Nitrate final SRM results



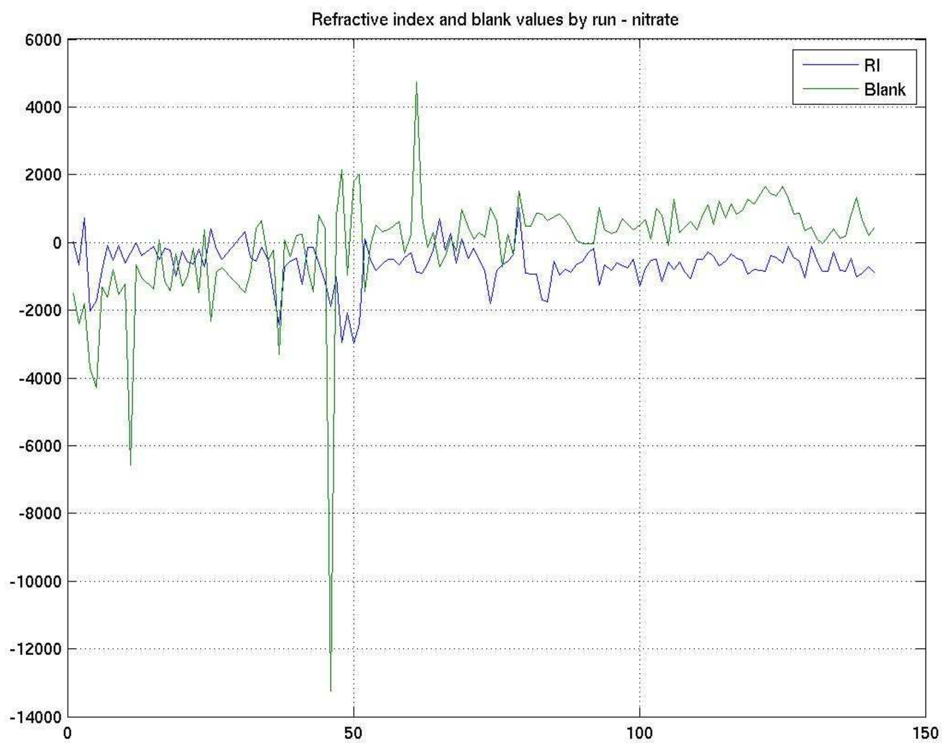
Phosphate final SRM results



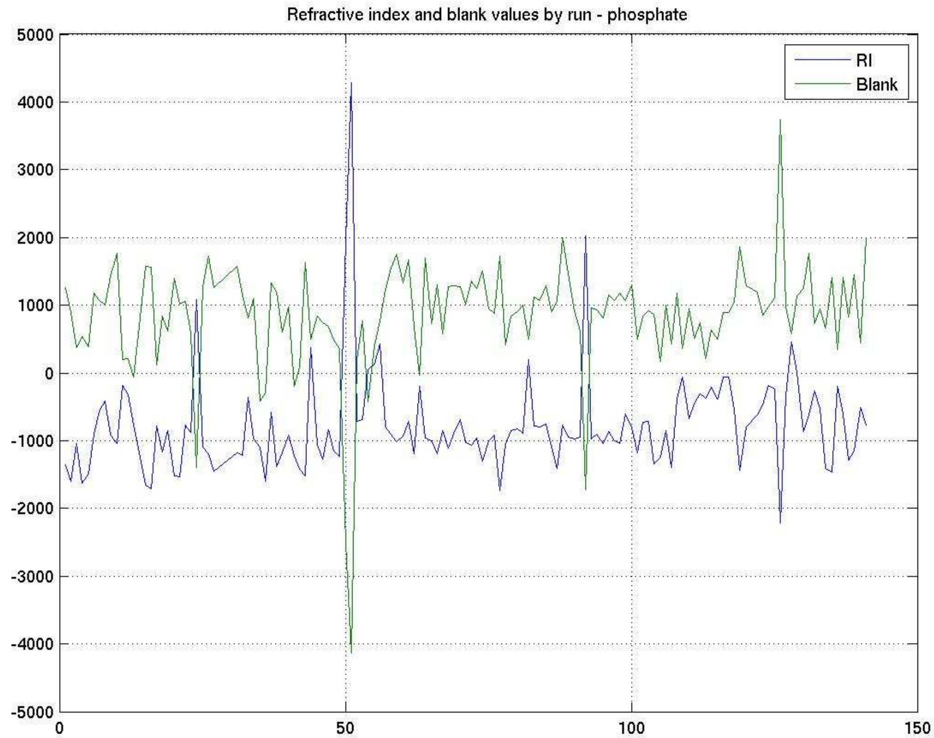
Silicate final SRM results



Nitrate blank and refractive index values



Phosphate blank and refractive index values



Silicate blank and refractive index values

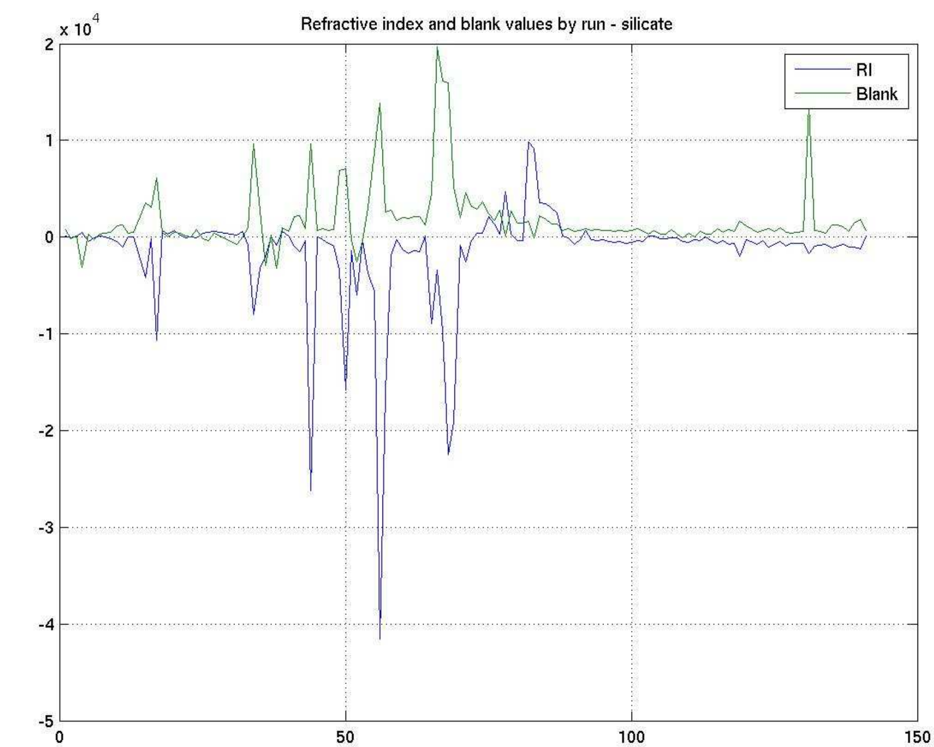


Table 5: Summary of corrections to the data made in step 2.

Run	Station	Nutrient	Adjustment
9	13	All	remove cal 4
13	17	All	remove cal 3 and 5
17	20	Ni	Remove cal 5
18	21	All	Remove cal 5
22	25	Ni	Remove cal 5
34	34	Ni	Remove cal 5
39	39	Ni	Remove cal 5
46	46	Ni	Re-import data
46	46	Ph	Bad result RP19, delete
57	57	All	Remove cal 5
58	58	All	Remove cal 5
59	59	Ni	Remove cal 5
60	60	All	Remove cal 5
61	61	All	Remove cal 3
63	63	All	Remove cal 5
64	64	All	Remove cal 4
65	65	Ni and Ph	Bad second cal 5, adjust to 1980100 (ni), 103000 (ph)
71	71	Ni	Use -28573 and -33120 as cal 0 value
72	72	Ni	Bad second set of calibrants, duplicate first set
79	79	All	remove cal 4
84	84	Ni	Bad second set of calibrants, duplicate first set
85	85	Ni	Remove cal 3 and cal 5
89	89	Si	Remove cal 1
96	96	All	remove cal 4
97	97	All	remove cal 5
98	98	All	remove cal 5
123	123	All	Bad calibration, remove all data
126	126	All	Remove cal 5
130	130	All	Remove cal 5
131	131	All	Remove cal 5
132	132	All	Remove cal 5
133	133	All	Remove cal 2
134	134	all	Bad calibration, remove all data
136	136	All	Remove cal 4
141	88	phosphate	Remove cal 5, re-import phosphate data from stn88, call it run 141
59 to 64	59 to 64	Ni	Correct to QC result of run 55
37	37	Ni	Flag sample 3712 as bad
46	46	P	Flag sample 4619 as bad
70	70	Ni	Flag all data as bad

References

WOCE Operations Manual, Volume 3. WHP Office Report WHPO 91-1. WOCE Report No. 68/91. November 1994, Revision 1.

CSIRO Hydrochemistry Operations Manual (1999). Cowley, R., Critchley, G., Eriksen, R., Latham, V., Plascke, R., Rayner, M., Terhell, D.

CCHDO DATA PROCESSING NOTES

Date	Contact	Data Type	Action/Summary
12/15/08	Cowley	NUTs	Submitted; no header, lat/lon
	Status: public Name: Cowley, Rebecca Institute: CSIRO Marine and Atmospheric Research Country: Australia Expo: Line: I05, I09, I02, I10 (parts of each) Date: 2000-09-26 Action: Merge Data Notes: This file contains re-processed nutrient data (November, 2008). The salinity and oxygen data are also included. Nutrient results are in um/kg, WOCE flags are included for the nutrients only. A PDF document describing the re-processing is available from Rebecca Cowley. Voyage PI is Susan Wijffels.		
10/13/09	Kappa	Cruise Report	Prepared text and pdf cruise reports
	Compiled report from: • Docs submitted by PI • Docs obtainted from CSIRO web site: http://www.marine.csiro.au/marq/edd_search3.rvdata1?lPla=FR&lVoy=9&lVyr=2000&lDtp=All&cSub=View+available+datasets Copyright CSIRO Australia, 2004 • CCHDO Data Processing Notes Placed docs in online directories		